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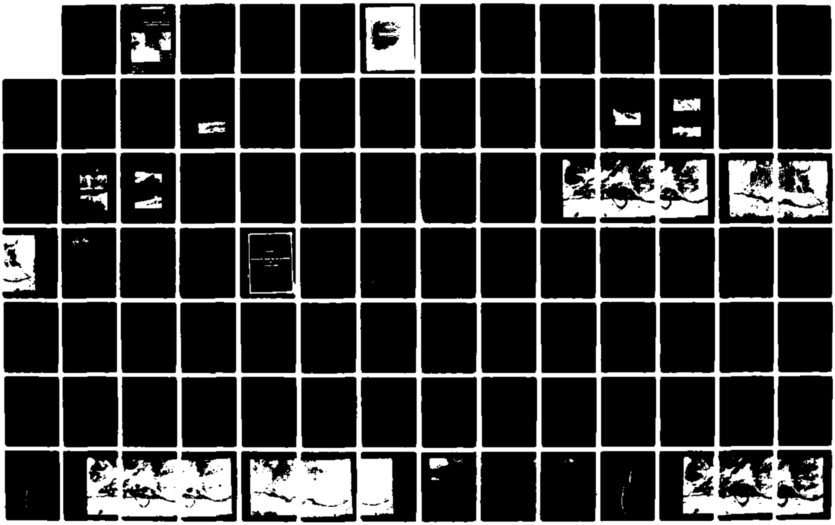

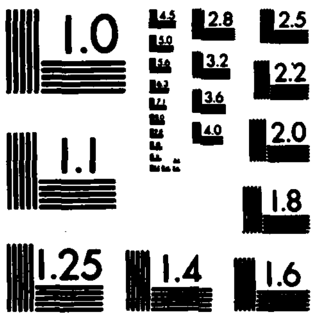

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review report for flood control and recreational development

little colorado river at holbrook, arizona

VOLUME II

TECHNICAL APPENDIX

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REVIEW REPORT

FOR FLOOD CONTROL AND RECREATIONAL DEVELOPMENT
LITTLE COLORADO RIVER AT HOLBROOK, ARIZONA

VOLUME II
TECHNICAL APPENDIX

SEPTEMBER 1980

VOLUME II
TECHNICAL APPENDIX

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SECTION A

PROBLEM IDENTIFICATION

1. This section describes prior and current water resource related studies in the Holbrook area and presents the process followed in defining this study's planning objectives.

PRIOR STUDIES AND REPORTS

2. The "Report on Survey, Flood Control, Little Colorado River and its Tributaries Upstream from the Boundary of the Navajo Indian Reservation in Arizona," completed by the Los Angeles District in 1940, recommended and led to the Congressional authorization of the construction of a levee along the right bank of the Little Colorado River at Holbrook, Arizona. A "Definite Project Report on Colorado River Basin, Little Colorado River Levee, Holbrook, Arizona", completed in 1946, reaffirmed the findings of the survey report and led to the construction of the Holbrook levee in 1948.

3. The U.S. Soil Conservation Service is currently involved in a River Basin Study of the Little Colorado River. The study, undertaken under the basic authority of the Watershed Protection and Flood Prevention Act of 1954, PL 83-566, is evaluating land treatment and other conservation measures on the river watershed, and is expected to be completed in June of 1980. Working papers on specific study items will be released before that date. Although this study may suggest methods of reducing sedimentation in the future, it will do nothing to relieve the current flood problems at Holbrook.

4. The Federal Insurance Administration is currently studying the Holbrook flood plain. A detailed Flood Insurance Rate Map will be published when the study is completed. Holbrook will then be able to upgrade their participation in the National Flood Insurance Program from the Emergency Program to the Regular Program.

5. Under a Corps of Engineers contract, the Museum of Northern Arizona conducted a cultural resource survey including identification of significant archeological and historic resources of the study area. The contractor and the Arizona State Historic Preservation Officer coordinated the study with one another.

BASE CONDITION

General

6. Holbrook is located in northeastern Arizona on the Little Colorado River below its confluence with the Puerco River (see pl. A-1). The town is located on a high desert plateau at about 5,000 feet above

mean sea level and is about 150 air miles and 200 highway miles northwest of Phoenix, Arizona's major city and the State capital.

7. Holbrook was founded in 1882 when the Atlantic and Pacific Railroad (later purchased by the Santa Fe) built a bridge over the Little Colorado River and established a railroad station. The town became a supply point for the numerous ranches and trading posts scattered throughout the outlying areas. Holbrook became the Navajo County Seat in 1895 and has since experienced growth in government services. After the completion of U.S. Route 66 through Holbrook, the town became a stop-off point for automobile travelers. Because of the proximity of the Hopi and Navajo Indian Reservations, the Painted Desert, and the Petrified Forest National Monument, tourism has become a mainstay of the Holbrook economy.

Physical Setting

8. The following paragraphs describe Holbrook's climate as well as its mineral, water and air resources.

9. CLIMATE. Holbrook has a semiarid or sub-humid climate characterized by low rainfall, hot summers, and fairly cool winters. During the summer months, daytime temperatures are usually in the mid-90's and night temperatures are usually in the high 50's and low 60's. January, the coldest month, has an average high of 48 degrees Farenheit and an average low temperature of 19 degrees Farenheit. Holbrook averages about 9 inches of precipitation annually. Within the drainage basin, precipitation varies from about 7 inches at Winslow and the Great Basin Desert to 40 inches at Baldy Peak in the White Mountains, the highest point in the drainage area. Afternoon showers and thunderstorms are common in midsummer, normally the wettest season in Holbrook. Winter precipitation is subject to large annual variations in both frequency or intensity. May and June are the driest months.

10. SURFACE WATER HYDROLOGY. The Little Colorado River originates in the White Mountains on the Arizona-New Mexico border and flows about 320 miles west into the Colorado River. It is the principle stream in the region, draining about 27,800 square miles in Arizona and New Mexico. The two major tributaries in the study area, the Puerco River and Leroux Wash, drain about 2,900 and 830 square miles, respectively. Above Holbrook, the Little Colorado River drains about 11,300 square miles.

11. Streamflows in the Little Colorado River at Holbrook vary greatly from month to month and from year to year. Streamflow is derived primarily from seasonal storms. Most annual peak flows occur in the July through October period. Most flows in the river occur during and immediately after storms. In much of the drainage basin, the flows of the Little Colorado River, the Puerco River, and Leroux Wash are ephemeral, drying up during the summer. The Little Colorado River at Holbrook is perennial. During certain periods flows in the Little Colorado become subsurface through the deep alluvium at Holbrook, rising

back to the surface near Penzance. The river receives limited flows from irrigation runoff, and to an unkown extent, from seepage from the Coconino aquifer.

12. The tributaries and main stem of the Little Colorado River are largely unregulated. Although about 26 dams, with an estimated aggregate storage capacity of more than 150,000 acre feet, are located in the basin, they are relatively small projects designed for irrigation, water supply, and recreation and provide minimal flood control. The 6-foot-high Penzance diversion structure is located about 7 miles downstream from Holbrook.

13. A detailed description of the hydrologic studies conducted for this report and the data acumulated and derived from those studies is contained in Section F of this appendix.

14. SURFACE WATER QUALITY. Dissolved solids in the waters of the Little Colorado River generally exceed 500 milligrams per liter (mg/1) during normal flows and exceed 1,000 mg/1 during summer low flows. This level of water quality is typical for rivers throughout the dry southwest. The mineral composition of the flow is predominantly calcium sulfate, which comes largely from tributaries draining the arid lands to the north such as the Puerco River. Tributaries from the south drain vegetated and forested areas near the Mogollon Rim and probably contribute relatively little mineralization.

15. Sources of runoff in the project region other than rainfall and snowmelt include treated sewage discharges at Holbrook and Joseph City and untreated agricultural return flows. Although these discharges contribute phosphate and nitrate to the river, the discharges are minimal in the study area and contribute detectable concentrations only during low river flows. The Cholla Power Plant also releases soluble minerals into the river.

16. GROUND WATER. The Little Colorado River basin in the vicinity of Holbrook is underlain by large quantities of ground water. South of the river, ground water occurs primarily in the Coconino sandstone bedrock; north of the river, ground water is contained primarily in the alluvium. The water contained in the Coconino sandstone aquifer, some of which is under artesian pressure, is of high quality and is the domestic water supply for Holbrook. This resource is also tapped for other uses, such as for cooling water at the Cholla power plant and for local agriculture.

17. Over the years, however, ground water levels have been decreasing because of excessive pumping, and water quality has been deteriorating. Although ground water quality is still high, this trend is expected to continue into the future, and a lower water table may cause water flowing in the Little Colorado River to enter the depleted Coconino aquifer. Local residents are concerned about intrusion of poor quality water from the ground water basin north of the river into the ground water basin south of the river from which water supplies are obtained.

18. AIR QUALITY. The air quality in the Holbrook area is generally very good and visibility is usually high. Although no Federal, State, or county air-monitoring stations are within 100 miles of Holbrook, a monitoring program was established in 1973 at the Cholla power plant about 12 miles west of Holbrook. This program is aimed primarily at determining the impact of the plant on the surrounding air quality.

19. The Cholla Power Plant relies on pollution control devices and atmospheric dispersion to meet the emission standards. Under normal conditions the emissions leave the 550 foot stack and are blown generally north-east in the aproximate direction of Holbrook. Since 1973, monitoring stations operated by the Arizona Power Plant Service have taken measurements near Holbrook, Woodruff, the Petrified Forest National Park, Winslow, and Joseph City. These indicate that while concentrations of nitrogen, sulphur and fly ash may vary over the day and throughout the year, the levels are usually far below government standards and rarely exceed established emission limits. Comparison of pollution levels and weather patterns suggests that sources of particulate matter and nitrogen-oxides may exist in the area. The highest levels of particulate matter were recorded during wind storms blowing dust from the surrounding lands. Nitrogen-oxide levels were marginally higher in cities than in rural areas, suggesting that automobiles may contribute detectable pollution levels. During rare situations, inversion layers may set in which keep pollutants from dispersing and may temporarily increase levels above government standards. However these events are of short duration and low intensity; they are not considered to seriously affect the overall high regional air quality.

20. NOISE. Highway and rail traffic are the only large sources of noise in Holbrook. Highway traffic presently passes through the heart of town on U.S. 66. Upon the completion of Interstate 40, the principal through-traffic corridor will be shifted to the north edge of town, and the stop-and-go traffic of present conditions will be replaced to considerable extent by faster moving through traffic. Although the faster traffic may produce a somewhat greater volume of noise, the change in location will probably result in a smaller number of people being affected. The change in highway location will also change the area affected by highway noise from a business-industrial area to a residential area.

21. Rail traffic noise in Holbrook emanates primarily from the Atchison, Topeka and Santa Fe Railway mainline, which passes east to west through town just south of the main business district. Noise results from both through traffic and local shifting operations.

22. MINERAL RESOURCES. Coal, which is probably the most important mineral resource found in northeastern Arizona, is being increasingly exploited and is to a large extent used in producing electrical power. Other minerals mined in northeastern Arizona include oil, natural gas, helium, uranium, vanadium, bentonite, and sand and gravel. Small-scale mining of iron ore and asbestos is also conducted in the Holbrook area. None of these minerals are mined or processed in the study area.

Biologic Resources

23. A description of the vegetation, wildlife, and threatened or endangered species within the Holbrook area follows. A detailed list of species found in the area is available at the Los Angeles District Office of the Corps of Engineers. Appendix A of this report, "Public Views and Responses," includes a U.S. Fish and Wildlife Service letter, dated 14 February 1977, identifying habitat in the area under study and suggesting methods of minimizing damage to fish and wildlife resources. Appendix B, "U.S. Fish and Wildlife Service Draft Coordination Act Report," dated 12 July 1978, provides the Fish and Wildlife Service views and recommendations to provide full consideration for fish and wildlife resources in project planning, development, and operation.

24. VEGETATION. The Holbrook study area is within the Upper Sonoran Life Zone. The major plant communities in the project study area are riparian, shadscale scrub, short grass, and Great Basin desert scrub. Except for large trees and shrubs associated with the riparian community, grasses and some small shrubs dominate the study area. The vegetation, which is sparse, is generally about 1 to 3 feet high and is characterized by a limited number of species. Salt cedar dominates the deciduous riparian community along the channel and in the high water table portions of the flood plain. Other species include cottonwood, willow, seep-weed, sycamore, cattail, and saltgrass. The dominant salt cedar was introduced in 1936 to control erosion. Artesian wells provide the water source for the cattails.

25. The shadscale scrub community along the flood plain is interspersed with riparian growth but is less dependent upon a high water table. The dominant shrubs in this community are shadscale and fourwing saltbush, greasewood, New Mexico or desert olive, rabbitbrush, black bush, and snakeweed. Such grasses as blue and black gamma, galleta, Indian ricegrass, saltgrass, and alkali sacaton are common.

26. FISH AND WILDLIFE. Native fish species that once inhabited the Little Colorado River include the Colorado chub, speckled dace, Little Colorado spinedace, bluehead sucker, and Sonora sucker. It is highly unlikely that these species currently exist in the study area because of the flow modifications that have occurred in the Little Colorado River near Holbrook. The river currently provides habitat for a small variety of largely or perhaps entirely introduced fish. These include black and brown bulkhead, killifish, fathead minnows, bluegill, and green sunfish. Amphibians along the river include tiger salamander, several species of toad, canyon treefrog, and leopard frog. Various lizard species and snakes, including the western rattlesnake, are found in the project study area.

27. The wildlife species frequenting the various habitats within the project study area are abundant and diverse. The most common and wide-ranging species (with the exception of birds) utilizing the grassland, flood plain, and mesa habitats are the deer mouse, valley pocket gopher, and desert cottontail and black-tailed jackrabbit. Other

species utilizing upland and/or riparian habitats include muskrat; beaver (signs observed at Penzance diversion structure on December 15, 1976); raccoon; striped skunk; ground squirrel; canyon, bush, and pinyon mouse; prairie dog; gray fox; coyote; and antelope. There have been local reports of porcupine in the study area.

28. Bird life in the study area is quite diverse. As many as 150 species utilize the habitats at various times of the year, and at least 31 species are residents breeding in the area. The riparian area attracts the greatest number of species because of the availability of food, nesting, and resting sources. During field surveys in January and March 1974 and December 1976, Corps biologists observed meadowlarks, mourning doves, starlings, house finches, juncos, crows, killdeer, flicker, mallards, Canada geese, great blue heron, and several species of sparrows. Many raptors (birds of prey) were observed during the March survey. Marsh, red-tailed, rough-legged, and sparrow hawks are common in the area. Soil conservation Service (SCS) biologists report prairie and peregrine falcon sightings in the area. The large trees and the high rodent population in the riparian area account for the large numbers of raptors. Ducks, geese, and shorebirds utilize suitable habitat along the river.

29. THREATENED AND ENDANGERED SPECIES. Phacelia cephalotes, a threatened plant species believed to exist in the Holbrook area, was not observed during a May 12, 1977, field investigation by Corps biologists. The little Colorado River spine dace, which is considered rare, utilized habitat in the headwater reach of the Little Colorado River. This species is apparently not found in the project study area where water supply is often intermittent. The only threatened or endangered species that possibly use the project study area habitats or feed within the regional study area are the bald eagle and the American peregrine falcon. The Arizona Department of Game and Fish reports migrating bald eagles may rarely visit the area. The peregrine falcon has been occasionally seen in the area.

Cultural Resources

30. ARCHAELOGICAL, HISTORICAL, AND CULTURAL RESOURCES. Like much of the southwest desert region, the Holbrook area is rich in Indian history. There is physical evidence of Indian occupation of the region 12,000 years ago. Indian cultures that have occupied the area include Tolchaco, Basketmakers, Pueblo, Hopi, Navajo, and probably Apache.

31. Despite the abundant history of the Holbrook area, (Also see prior paragraph, "General.") a detailed cultural resource study of the riverbed and flood plain of the Little Colorado River that might be disturbed by a potential flood control project exposed no potential archaelogical or historic sites requiring preservation. A report dated December 1977, and titled "An Intensive Archaelogical Survey of Proposed Rechannelization Areas and Associated Levees Near Holbrook, Navajo County, Arizona," contains the results of the survey, which was conducted under contract to the Corps of Engineers. This report is included in Section C of this appendix, "Cultural Resources."

32. RECREATION. Holbrook's recreational facilities include three municipal parks: Ben Hunt Park (8 acres), Lisitski Park (5 acres) and the 2 acre Lewis Park (see pl. A-1). Although these parks are not fully developed, they do provide facilities for baseball, tennis, basketball, and playgrounds. There are no designated bikeways in the Holbrook area. Public picnic tables are limited to a three-table development at Lisitsky park.

Economic Resources

33. ECONOMIC BASE. Holbrook is a trade center for the Navajo and Apache Counties. Development of the automobile and modern highway caused a growth in tourism which supported growth in the trade sector and caused the service sector of the Holbrook economy to be equal to trade. Because of its status as Navajo County seat and because of its central location in relation to the "four corners" area and the Navajo and Hopi Indian Reservations, Holbrook has become a center for government. Other industries contributing to Holbrook's economic base include agriculture, forestry, construction, manufacturing, transportation, communications, and public utilities.

34. EMPLOYMENT. Because of substantial unemployment, Navajo County is currently designated a Title IV redevelopment area by the Economic Development Administration of the U.S. Department of Commerce. As of October 1979, there was 11.7 percent unemployment in the county. Title IV designation qualifies areas for public works grants and low interest loans.

35. Table A-1 shows employment in Navajo County and in Holbrook by industry, and table A-2 provides statistics on employment by occupation.

36. INCOME. Across the nation, about 14.4 percent of the population subsists on income below the poverty level. The residents of Holbrook are somewhat behind the rest of the nation, with 15.5 percent having incomes below the poverty level. A small low-income community exists on the south side of the Little Colorado River. Incomes in Navajo County compare very poorly with the rest of the nation. The 39 percent of county residents with less than poverty level income undoubtedly reflects the large, rural Indian population.

Table A-1. Employment by industry (1970)

(In percent)

Industry	Navajo County	Holbrook
Agriculture, forestry, and fisheries	3.8	2.0
Mining	1.0	0
Construction	8.4	8.2
Manufacturing	13.8	2.5
Transportation	9.4	3.1
Communications and public utilities	3.3	8.4
Trade	18.9	29.7
Finance, insurance real estate	1.9	2.4
Services	30.9	32.0
Government	8.6	11.7

Source: 1970 U.S. Census of Population and Housing.

Table A-2. Employment by occupation (1970).

(In percent)

Occupation	Navajo County	Holbrook
Professional, technical and related	14.5	16.3
Nonfarm managers and administrators	12.4	14.9
Sales workers	4.0	6.0
Clerical workers	12.8	17.9
Craftsmen, foremen, and related	15.7	12.3
Operations, except transport	8.5	4.3
Transport operations	5.3	4.6
Nonfarm laborers	7.9	3.7
Service workers	14.4	18.4
Private household workers	2.0	1.3
Farm workers	2.5	0.2

Source: 1970 U.S. Census of Population and Housing.

37. TRANSPORTATION. Holbrook is served by all forms of transportation and, in turn, serves as a depot for much of the surrounding area. Major highways passing through Holbrook include U.S. 66 (Interstate 40), U.S. 180, and State Route 77. Rail service is provided to Holbrook by the Santa Fe Railway and the Apache Railroad, which connects Holbrook to Snowflake and the Rim country to the south. One Amtrak train per day passes each way through Holbrook but does not stop there. The nearest stop is at Winslow, about 30 miles to the

west. Bus service is provided by Greyhound, Continental Trailways, and White Mountain Passenger Lines. Truck lines providing common carrier and tanker service to Holbrook include Navajo Freight Lines, United Parcel Service, Thunderbird Freight Lines, and some smaller local companies. The Holbrook Municipal Airport has two lighted runways of 3,200 and 5,000 feet in length. The community is serviced with one flight per day to Phoenix, Arizona and Farmington, New Mexico. Other nearby cities with scheduled airline service are Flagstaff, Arizona, 91 miles to the west, and Gallup, New Mexico, 95 miles to the east.

38. LAND USE. Although 94 percent of the land in Navajo County is either vacant or used for grazing, much of the land within Holbrook is developed to residential, commercial, public, and industrial uses. After establishment of the railroad station, the town clustered just north of the Little Colorado River in the flood plain below the mesas. Subsequent development of the transportation corridors contributed to development in this location. Almost all of the community's businesses and residences, as well as the high school, are located here. Some development has occurred south of the river, but these structures have suffered from deterioration, partly because they are separated from downtown by the river and partly from past flooding. In many cases substandard housing exists in this area (see photo A-1). Navajo County has recently relocated its government center and fairgrounds a few miles south of the river along State Highway 77. Recent development has occurred along Highway 66 on the bluffs north of town. The pace of expansion to the north, in the vicinity of Holbrook Airport (see pl. A-1), is expected to quicken with the completion of Interstate 40.

Photo A-1. Development on south side of river.

39. Of the 2,600 acres in the vicinity of Holbrook subject to inundation by the Little Colorado River, about 500 acres are in urban use. Approximately 854 structures, including 632 homes and 26 mobile homes, are within the standard project flood overflow area. The flood plain also includes the central business district with most of the city's commercial development; all schools in the city; most of the limited industrial development; many churches; and Federal, State, and local government buildings. Land use in the flood plain by type of use is given in table A-3.

Table A-3. Present land use by flood (units).

Land use	SPF*	100-Year	50-Year
Single-family residential			
Conventional	632	600	600
Mobile homes	26	26	26
Commercial			
Auto repair and sales	13	13	13
Strip	75	75	75
Two story	4	4	4
Motels	18	18	18
Restaurants	12	11	11
Gas stations	14	14	14
Public			
Office	15	15	15
Schools	11	10	10
Semipublic-churches	10	10	10
Industrial			
Warehouses	10	10	10
Manufacturing	15	15	15

*Standard project flood.

Social Resources

40. Following is a description of the demographic, housing, and esthetic environment in the Holbrook area.

41. In 1970, Holbrook had a population of 4,759, and Navajo County had 47,559 residents. The estimated 1978 population for Holbrook ranges from 5,150 to 5,500 and for Navajo County between 47,600 and 66,380. Table A-4 shows historic and projected population for Holbrook and Navajo County.

42. The racial composition of Navajo County in 1970 was 49.1 percent white, 48.3 percent American-Indian, 1.9 percent black, and 0.7

medians were 19.9 and 18.9 years for females and males, respectively. Table A-5 presents median age by sex, race, or ethnic group for Navajo County and Holbrook.

44. The 1970 census showed that 58.7 percent of Holbrook residents over 25 years of age have completed high school; this compares with 58.5 percent of the County's residents over 25, who have completed high school. Table A-6 shows educational attainment by Holbrook and Navajo County residents.

Table A-4.

Historic and future population

Area and Source	1960	1970	Percent Change	1979	Percent Change	1980	Percent Change	1990	Percent Change
Little Colorado River Basin*									
Office of Business Economics—Economic Research Service (OBERS)	105,641	124,139	17.5	124.300	0.1	124.400	0.1	130,900	5.2
University of New Mexico, Bureau of Business and Economic Research and Northern Arizona Council of Governments	105,641	124,139	17.5	175,700	41.5	194,100	10.5	240,000	23.6
Navajo County									
OBERS	37,994	47,559	25.2	47,600	0.1	47,700	0.2	50,200	5.2
Northern Arizona Council of Governments	37,994	47,559	25.2	71,000	49.3	75,800	6.8	100,400	32.5
Holbrook									
OBERS	3,438	4,759	38.4	5,150	8.2	5,250	.9	5,500	4.8
Northern Arizona Council of Governments	3,438	4,759	38.4	5,500	15.6	5,800	5.5	7,000	20.7

Sources: 1960-1970 U.S Census; University of New Mexico, Bureau of Business and Economic Research; and Northern Arizona Council of Governments.

*Includes Navajo and Apache Counties in Arizona, and McKinley County in New Mexico.

Table A-5. Median age in Navajo County and Holbrook (1970) by sex, race, or ethnic group. (In years)

Group	Navajo County	Holbrook
Female		
White	24.7	23.6
Black	22.3	17.7
American-Indian	16.8	17.1
Spanish-American	17.2	21.8
All females	19.9	22.0
Male		
White	23.7	21.9
Black	18.1	18.2
American-Indian	16.2	12.4
Spanish-American	16.9	16.6
All males	18.9	20.1
Total	18.9	21.4

Source: 1970 U.S. Census of Population and Housing.

Table A-6. Median level of educational attainment (1970) by race or ethnic group. (In years)

Group	Navajo County	Holbrook
White	12.3	12.4
Black	8.4	7.8
American-Indian	7.2	8.4
Spanish-American	10.0	10.4
Total	10.7	12.2

Source: 1970 U.S. Census of Population and Housing.

45. ESTHETICS. Excellent high desert weather and air quality prevail in the Holbrook area. Scenery in the surrounding area is typified by usually bright blue skies and small mesas of red rock protruding from red and brown desert soils decorated with golden grasses and small shrubs. The Little Colorado River bed near Holbrook contains thick vegetation, including dense salt cedar growth and some exceptionally fine stands of old cottonwood trees. In summer, the lush riparian growth provides a pleasant contrast to the more barren desert surroundings. A locally dug low-flow channel, the north-bank Corps levee, the south-bank levee—composed partly of rough rubble and car

bodies, and the Penzance diversion structure are the only significant modifications of the Little Colorado River and the immediately surrounding flood plain through the project study area. Otherwise, the river bottom retains a natural character. Substandard housing structures occupy parts of the flood plain north and south of the river through the City of Holbrook.

46. HOUSING. A temporary increase in population resulting from an influx of construction workers working on the Cholla power plant expansion has contributed to a housing shortage in Holbrook. Whether and to what degree the shortage will continue after completion of units 3 and 4 in 1981 is not clear.

47. Another factor contributing to the housing shortage has been the lack of flood-free sites close to available utilities. The town is currently in the process of expanding water and sewer facilities on the bluffs north of the central part of town. This action should help to improve the availability of housing.

48. Most of the present housing in Holbrook is in reasonably good condition, although there are pockets of substandard housing, the largest of which is located on the south side of the Little Colorado River in the vicinity of State Route 77. (See discussion under "Land Use" above).

49. UTILITIES. With the exception of natural gas, Holbrook is adequately supplied with all necessary utilities. A moratorium on new natural gas hookups has been in effect for some time, but efforts are being made to find new supplies so that the moratorium can be lifted.

50. Domestic water in Holbrook which is supplied by the Holbrook Water Department is obtained from three local wells tapping the Coconino sandstone aquifer. Transmission is through city-owned lines. The recent completion of a new 18-inch main will satisfy the city's needs for the foreseeable future. Smaller delivery mains are constructed by the city as required.

51. Holbrook is currently conducting a program of upgrading its sewer mains. The city-owned sewage treatment plant, located west of Leroux Wash was constructed in cooperation with the Environmental Protection Agency (EPA). There are plans to upgrade the plant to satisfy new EPA criteria.

52. Electricity is supplied to Holbrook by the Arizona Public Service Company, which is in the process of a massive expansion of its Cholla power plant located at Joseph City, about 10 miles west of Holbrook.

53. Telephone service is supplied to Holbrook by the Western States Telephone Company.

Existing Flood Control Facilities

54. Two dams - Zion Dam and Lyman Dam - are present on the Little Colorado River upstream from Holbrook. Zion Dam, about 50 miles upstream from Holbrook, was almost completed in 1905, but was destroyed by a flood before it could be finished. It was rebuilt in 1908. The reservoir had a capacity of about 13,000 acre-feet, but continued silting has rendered the reservoir unusable. Lyman Dam, about 20 miles upstream from Zion Dam, was destroyed in 1915 and rebuilt in 1920. The water conservation reservoir, with its present capacity of 32,200 acre-feet has a contributing drainage area of 790 square miles, but has no flood control storage space other than incidental space that may be available during normal water conservation operations. Many of the tributaries of the Little Colorado River contain numerous small dams and reservoirs (less than 1000 acre-feet) that are used for water conservation. None contain dedicated flood contol space, nor do they have any effect on peak flows at Holbrook.

55. The Corps of Engineers constructed a levee on the north bank of the Little Colorado River at Holbrook in 1948 (see pl. A-1). The levee was designed for a flow of 60,000 cubic feet per second (cfs). The selection of this design flood was based on an estimate of the discharge of the largest flood of record (Sept. 1923) on the river at Holbrook. This discharge is now considered to be a 100-year flood. Since 1948, however, changes or unanticipated processes in the drainage basin and riverbed have reduced channel capacity. Soil erosion in the watershed has occurred in the past due to natural and geological processes. Overgrazing in the drainage basin above Holbrook has contributed to sediment production. The sediment moves down the steep riverbed in the upper basin and begins settling out in the vicinity of Holbrook, where the natural riverbed gradient decreases. Plants (primarily salt cedar) growing in the riverbed at Holbrook aggravate this sediment deposition. Another cause of sediment buildup is the unanticipated effect of the State Route 77 and Apache Railroad bridges, both of which were in place when the levee was constructed. All of the above have caused the bed of the Little Colorado River to rise since the levee was built. The existing capacity of the north levee is now estimated at 30,000 cubic feet per second, or about a 14-year flood. The existing levee extends from the Apache Railroad bridge to high ground 6,200 feet upstream. When the levee was built, neither the railroad bridge nor the State Route 77 bridge was reconstructed. The levee design included a 6-foot high miter gate to permit passage of traffic through the levee (see photo A-2). Although the owners raised the railroad bridge about 2 feet after it was damaged in the 1972 flood, the bridge would still be overtopped by a 100-year flood.

56. Over a period of years, local interests have built a dike of uncompacted earth and rubble to protect development on the south side of the Little Colorado River (see photo A-3). The dike between the river and Montano Street extends from a point about 800 feet east of Route 77 eastward and southward to higher ground, a distance of over 2,000

feet. During floods of about 15,000 cfs in 1972 and 25,000 in 1978, this levee, coupled with flood fighting efforts, prevented flooding of the south-side community.

57. After the 1972 flood, the City of Holbrook, assisted by Housing and Urban Development (HUD) in obtaining a used dragline, began excavating a low-flow channel in the river (see photo A-4). Over a period of 3 to 4 years city forces have dug a channel approximately 80 to 100 feet wide extending from near the confluence with the Puerco River downstream to Penzance Dam. The purpose of the low-flow channel is to speed flows through the reach and thereby reduce sedimentation. Sediments dredged from the channel are disposed on the banks and act as informal low-flow levees. Thus far, the channel seems to be working as planned, with the largest flow experienced to date about 25,000 cfs at Penzance, as estimated by the U.S. Geological Survey. Officials of Holbrook have expressed their intention to maintain the low-flow channel.

Photo A-2. Existing north levee and miter gate as viewed from south

Photo A-3. Uncompacted earth and rubble dike on south side of river

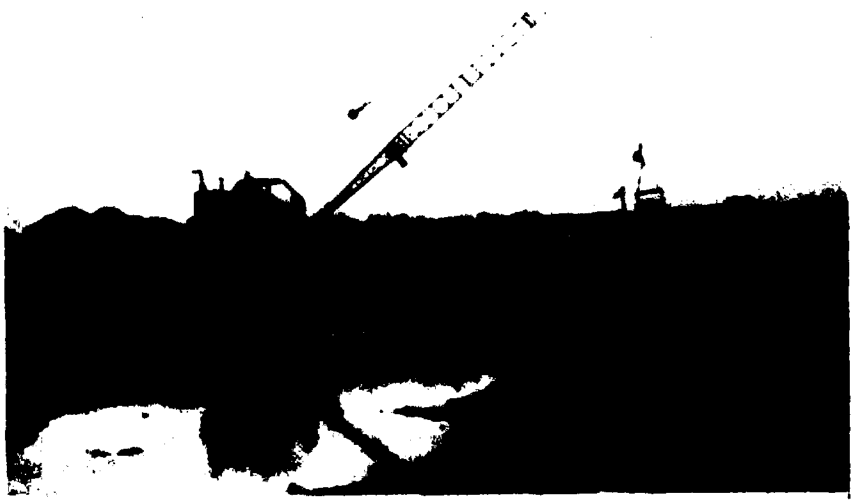


Photo A-4. Construction of existing low-flow channel

58. In addition, to its flood control efforts along the Little Colorado River, the City of Holbrook maintains an uncompacted dike forming a ponding area east of the old county fairgrounds. The dike and ponding area collect flows from two small streams flowing south from the vicinity of the airport and flowing west from a drainage area east of the town. The ponding area is used to retain floodflows until they can enter the Little Colorado River by way of a culvert through the Santa Fe Railway embankment and the existing Corps levee. The present system is not quite adequate to control a 50-year flood.

59. The City of Holbrook is currently enrolled in the emergency flood insurance program of the Flood Insurance Administration. A detailed rate study is expected to be completed this year.

CONDITIONS IF NO FURTHER ACTION IS TAKEN (WITHOUT CONDITION PROFILE)

60. The without condition is that which is most likely in the Holbrook area if no specific plans for future flood control or related developments are implemented. Because nearly all future development in Holbrook will occur on high ground north and south of the Little Colorado River flood plain, the assessment of the most probable future without condition is not sensitive to alternative assumptions of the rate and location of future development.

Population/Land Use

61. The town of Holbrook is expected to continue its past population growth. The town will expand as described under the previous seciton, "Land Use." A minor amount of development will occur on fill in the fringe area of the 100-year flood plain. This development will occur on vacant lots in the midst of developed areas. Construction of Interstate 40 will encourage the current trend of developing the mesa to the north of downtown. The recently constructed county governmental center and new county fairground will attract development to the south of the Little Colorado River flood plain.

Employment

62. The high unemployment rate which exists in Navajo County is expected to persist in the near future, and may be worsened upon completion of units 3 and 4 of the Arizona Public Service's Cholla Power Plant in Joseph City. These units will be completed in 1980 and 1981, respectively.

Flooding

63. The town of Holbrook is expected to continue its program of maintaining a low flow channel in the river through town. This channel may minimize sediment deposition from low flows, but will do little to affect flooding from large flows. The main part of the town of Holbrook will remain subject to inundation from floods greater than 30,000 cfs.

64. Holbrook is expected to continue floodfighting measures during floods on the southside of the river. However, flooding is expected to occur in this area from discharges greater than about 25,000 cfs.

65. The Federal Insurance Administration (FIA) is currently studying the Holbrook flood plain. A Flood Insurance Rate Map, scheduled for completion late in 1980, will be published as a result of the FIA study. The map is a necessary step to allow Holbrook to upgrade their participation from the Emergency Flood Insurance Program to the Regular Program.

Recreation

66. County plans to develop the new fairgrounds south of town are expected to be implemented. Although 20 picnic tables will be installed, they will be available only during fairs. A municipal pool will be constructed in Holbrook, but no other major recreational facilities are planned.

Water Supply

67. The underground aquifer from which Holbrook obtains its water supply contains sufficient quantities to serve the city's needs for the foreseeable future, although more water is being drawn from the aquifer than is being replenished from natural sources. The city's distribution system has caused some short-term limitations on development in the past, but the construction of new mains and storage facilities is resolving these problems.

Water Quality

68. Since Holbrook's underground water supply is of high quality, requiring only chlorination before use, water quality does not present a problem. High salinity in the riverbed has limited diversification in vegetation although the construction of a low-flow channel by the city may speed saline flows through the area and encourage diversification (see "Vegetation," below).

Vegetation

69. Although other vegetation does exist in the Little Colorado Riverbed, as described above, the proliferation of salt cedar is expected to continue to dominate the riparian species. The high salinity of surface water flows will continue to limit the growth of vegetation in areas subject to frequent flows; this salinity limits the diversity of vegetation to salt tolerant.

PROBLEMS, NEEDS, AND OPPORTUNITIES

Flood Problems

70. FLOOD HISTORY. Little is known about flood damages occurring in the vicinity of Holbrook prior to 1938. It is known, however, that a 1923 flood had an estimated discharge of 60,000 cfs. Current hydrology indicates that this would be about a 100-year flood. Since 1939, knowledge of flooding is more detailed and includes the streamgage record from 1950 to 1973.

Annual peak flows; the Little Colorado River at Holbrook
(peak flow in cubic feet per second)

Date	Peak Flow	Date	Peak Flow
July 19, 1950	2,960	July 25, 1965	14,800
August 28, 1951	8,700	August 13, 1966	10,400
January 19, 1952	8,400	August 12, 1967	14,100
July 29, 1953	6,030	August 12, 1968	21,000
July 22, 1954	10,800	October 4, 1968	24,200
August 17, 1955	10,500	September 6, 1970	19,700
June 30, 1956	4,210	August 12, 1971	13,200
August 5, 1957	21,800	October 1, 1971	20,300
September 14, 1958	7,000	October 20, 1972	15,000
August 6, 1959	6,300	July 22, 1974*	3,880
October 29, 1960	11,400	October 29, 1974*	20,600
August 16, 1961	4,160	July 30, 1976*	3,880
October 31, 1962	4,010	August 18, 1977*	12,000
August 31, 1963	9,370	March 1, 1978*	5,200
September 9, 1964	15,100	December 19, 1978*	25,000

*Data from gage 09397000 discontinued in 1974. Data from 1974 through 1979 for the Little Colorado River at Joseph City, USGS Gage No. 09397300.

71. Damage and near disaster have occurred at Holbrook on three separate occasions since 1970. In September 1970 overbank flows up to 3 feet deep inundated unprotected property on the south side of the river (see photos A-5). The peak flow in the flood was about 19,700 cfs. During this flood, mud blocked the openings of the State Route 77 bridge and the Apache Railroad bridge. A year later, in September of 1971, a flood with a discharge of about 20,300 cfs nearly overtopped the upstream end of the existing levee on the north bank (see photo A-6). Had failure occurred, most of the main part of Holbrook would have been inundated. During the same flood, the railroad embankment at the downstream end of the Corps levee was nearly overtopped (see photo A-7); and the south side was inundated again. In October 1972, another flood estimated at about 15,000 cfs occurred. Only extensive floodfighting along the makeshift levee on the south-side of the river prevented south-side property from being inundated again. Improvement of the

south levee by local interests after 1972, coupled with floodfighting, prevented flooding of the south side by a flood estimated at 25,000 cfs in December 1978.

72. FUTURE FLOODING. Holbrook is subject to flood damages from two sources--the Little Colorado River and the small tributaries from the north and east. The threat from the Little Colorado River is by far the most serious.

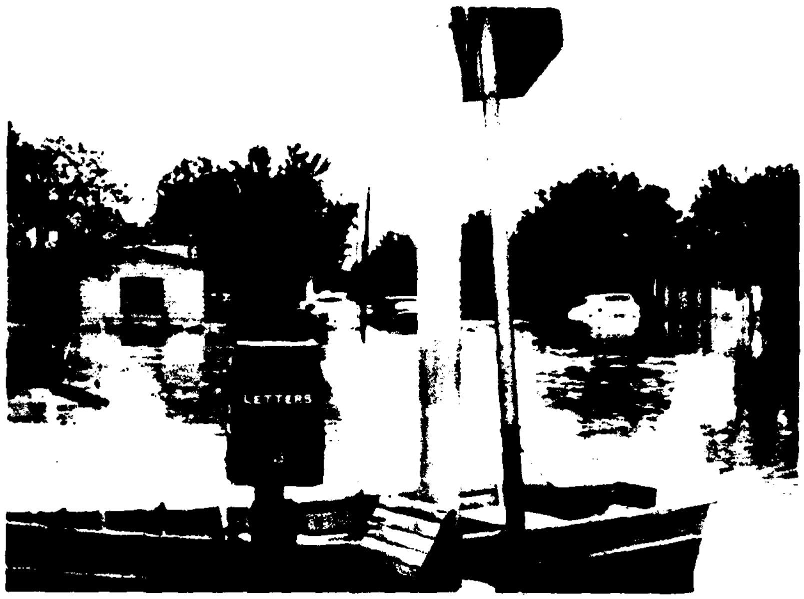


Photo A-5. Flooding south of river in 1970

Photo A-5 (cont.). Flooding south of river in 1970

Photo A-6. Existing north levee upstream of town almost overtopped in 1971

Photo A-7. Railroad embankment downstream of existing north levee almost overtopped in 1971

73. Flooding from the Little Colorado River. Flood damages from the Little Colorado River can be expected to occur from flows in excess of about 25,000 cfs (see pl. A-2). This size flood, which has a probability of occurrence of about 12 percent (about once in 8 years), could overtop the south-side dike. Once the south-side dike was overtopped, it could be expected to wash out very quickly. The Corps levee on the north side will contain flows up to about 30,000 cfs (about a 14-year flood). The Corps levee could be expected to withstand some overtopping flows; however, if the flood were large enough or of long enough duration, rapid failure could occur there, also. Much of the development in Holbrook on both sides of the river is near or even below the elevation of the streambed; and once overtopping of the levee and dike occurred, most of the town would be in danger of flooding. During the 100-year (1-percent-chance) and 50-year (2-percent-chance) floods, 821 structures would be damaged by flooding. Of these structures 796 are on the north side of the river and 25 are on the south side. During the standard project flood, 854 structures would be flooded, 804 on the north side and 50 on the south side. Should they occur (1979 conditions) damages from the SPF, 100-year and 50-year floods would exceed $27 million, $22 million, and $21 million, respectively. (See Section C, 'Economics", for details). In the heart of town and on the south side, 6- and 8-foot depths would be common during the 100-year and the standard project floods. Maximum flow velocities during these floods would be up to 5 and 7 feet per second, except near a levee break where velocities would be higher. Injury and loss of life would be highly probable should either the levee or the dike wash out during a large flood. The City of Holbrook has some arrangements for a "river-watch" or observation type of warning sytem. However, a large flood at Holbrook could result from large flows on the Puerco River or the Little Colorado River or both, and the unsophisticated observation system might not predict a large combined flow or provide adequate time for evacuation. Opportunities to reduce this flood threat exist through implementation of non-structural and structural flood plain management measures.

74. Flooding from tributaries. Flows from the small tributaries north and east of town can cause what might be characterized as nuisance flooding. Except for rare events, flooding would only occur on streets and lawns. The 50-year flood (see pl. A-3) could produce some isolated flooding inside buildings. A one-hundred year event could cause depths above ground of 0.5 to 2.0 feet. Flow velocities would range from 1 to 5 feet per second. Equivalent annual damages from tributary flooding are estimated at $48,000 (7-1/8 percent - 100 years). Because current authority precludes Corps participation in solving urban flood problems on streams with 10-year discharges less than 800 cfs and 100-year discharges less than 1,800 cfs, this problem was not pursued. However, the residual problem is displayed in the System of Accounts display under "Formulation, Assessment, and Evaluation of Detailed Plans."

Social Problems

75. The flood threat to Holbrook presents serious social problems. In addition to the potential for injury, sickness, and loss of life, hundreds of people would be forced from their homes during a major flood event. Because of the present housing shortage in Holbrook, which is not likely to abate in the near future, providing emergency housing for such a large number of people would be very difficult. Community activities and normal routines would be disrupted indefinitely. People affected by flooding would have to undergo the anxieties and frustrations of dealing with unfamiliar government agencies and regulations. Use of personal funds and time would be diverted to flood recovery activities instead of being used for improving quality of life.

76. Residents of the south side community would suffer all the flood related social problems of their north side neighbors plus some problems unique to the south side. Residents of the south side face a much more uncertain future than those in the main part of town. South side property owners who are financially able to improve their properties are prevented from doing so by the flood threat. Most of the south siders are poor and many live on fixed incomes in the only housing they can afford. Should their homes be destroyed or otherwise be made or declared uninhabitable, affordable alternative housing would not be available. Existing governmental programs for dealing with such a situation are indirect, time consuming and uncertain. People living at or near subsistence level incomes would find economic recovery slower and more difficult while waiting for government assistance and from losses not covered by government assistance.

Employment Problems

77. Persistent high unemployment in Navajo County can be reduced for the short-term by providing public works construction jobs.

Housing Problems

78. A shortage of housing exists because of the influx of construction workers at the Cholla power plant. Those workers who could not be accommodated by the existing housing stock are living in mobile homes. Upon completion of the plant this problem will be relieved. Substandard housing south of the Little Colorado River and adjacent to State Highway 77 poses a more permanent housing problem. Most the people living there are black and poor. A number of families have been moved from the area through a Farmers Home Administration (FHA) self-help program. Future development on the south-side flood plain is now controlled by a city ordinance that does not allow the issuance of building permits for the area except on the floodway fringe where 100-year flood protection must be provided in accordance with the Flood Insurance Act.

79. Supplemental payments for safe and sanitary housing under "The Uniform Relocations Assistance and Real Property Acquisition Policies

Act of 1970" may provide the opportunity to upgrade south-side housing in conjunction with flood plain management measures. Alleviation of the flood threat on the south-side would also tend to improve the condition of housing there

Recreation Problems

80. An inventory of recreational facilities of Holbrook was compared with demand for facilities included in the "State of Arizona Statewide Comprehensive Outdoor Recreation Plan," (1973) prepared by the Arizona Outdoor Recreation Commission. This comparison showed Holbrook to be deficient in most types of recreational facilities, especially family park and picnic facilities and trails. (See Section E, "Economic Evaluation of Alternatives.") According to Holbrook officials, all park and recreational facilities are currently used heavily by local residents and by Indian children who reside in Bureau of Indian Affairs dormitories when school is in session. Holbrook is currently deficient about 30 picnic tables and 14 miles of trail. The opportunity to make joint recreational use of rights-of-way required for flood control was investigated in this study.

Vegetation Problems

81. A highly saline surface water supply and the tenacity of salt cedar prevent a diversity of vegetation in the Little Colorado Riverbed. Opportunities to enhance the natural environment by diversifying the vegetative cover and thereby providing a more diversified visual environment and also providing vegetation with additional food value for wildlife should be pursued.

Study Area

82. The study area for formulation of alternative plans to address the water and related problems and needs in the vicinity of Holbrook and to assess the localized physical impact of these plans includes the Little Colorado River flood plain in the vicinity of Holbrook and areas upstream of the city that may provide suitable sites for flood management measures. For purposes of assessing economic, financial, and other far reaching impacts, the study area will extend to the City of Holbrook, the State of Arizona, and the Nation as a whole.

PLANNING CONSTRAINTS

83. Certain constraints limit the opportunity to resolve problems and needs as previously identified. These constraints include financial, economic, biological, social, and engineering considerations.

Financial

84. Holbrook's tentative 1978-1979 budget is about $3.6 million. Most of the operative budget is committed to ongoing programs. With a 1978 population of only 5,500, Holbrook's limited ability to fund additional programs may be a constraint.

Economic

85. The major economic constraint is the inability to formulate a plan(s) for which the benefits are in excess of the costs, or the benefit-cost ratio is greater than 1.0.

Biologic

86. Significant impacts on biologic systems, where there are not compensating benefits, would be unacceptable and will constrain the ability to resolve problems. Especially critical are potential impacts on threatened and endangered species, and on the limited diversity of riparian habitat.

Social

87. Severe dislocation of people, destruction of neighborhoods, irritation of the existing limited housing market, and other social considerations constrain the ability to resolve problems and needs. Residents on the south side of the river are connected to downtown services by the State highway 77 bridge. Although a bypass is currently planned, many who use the bridge for pedestrian access to town will continue to need the existing bridge.

Safety

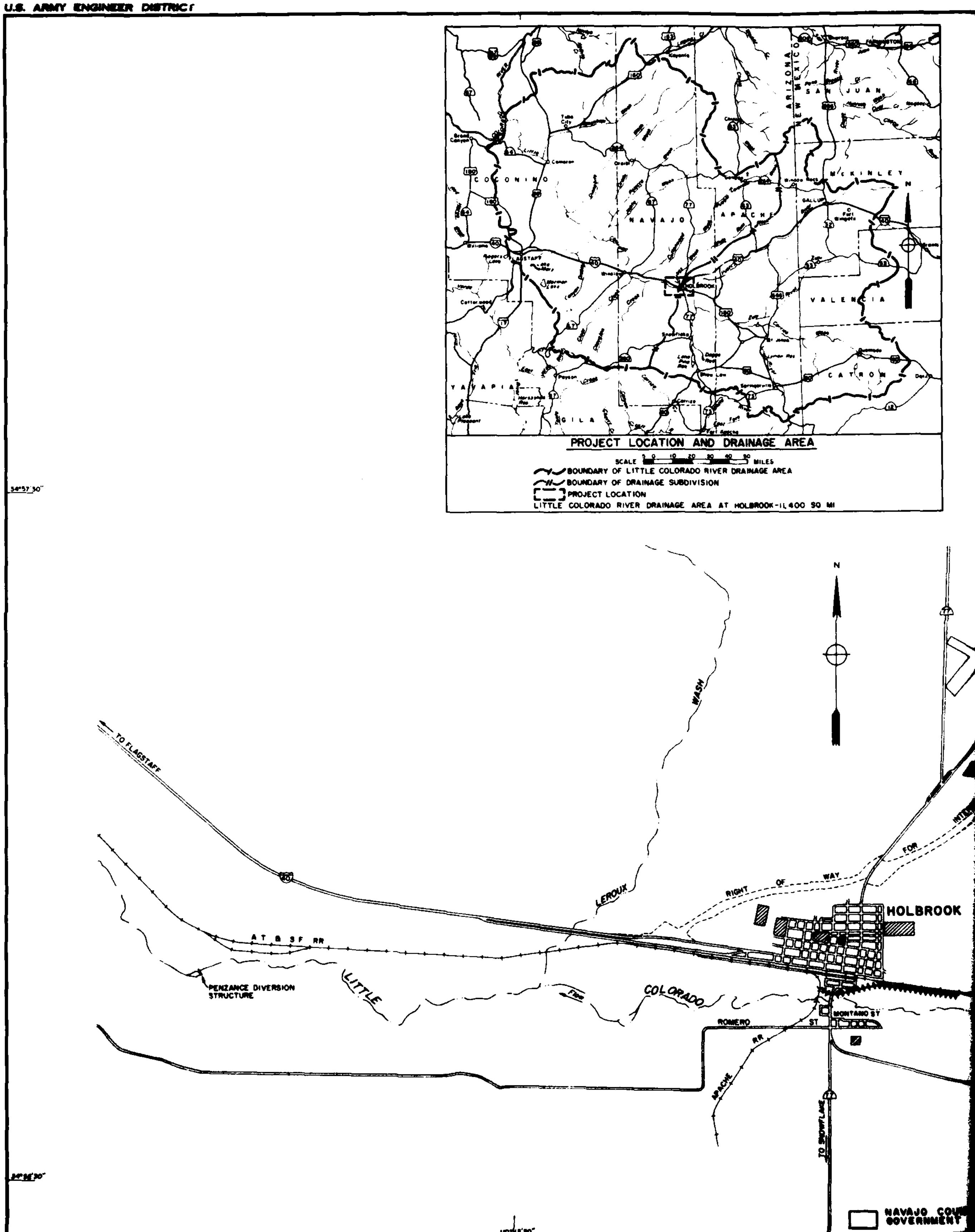
88. Safety considerations, including the policy of not constructing levees to less than the SPF level of protection, if overtopping and failure can result in a catastrophe, constrain the study.

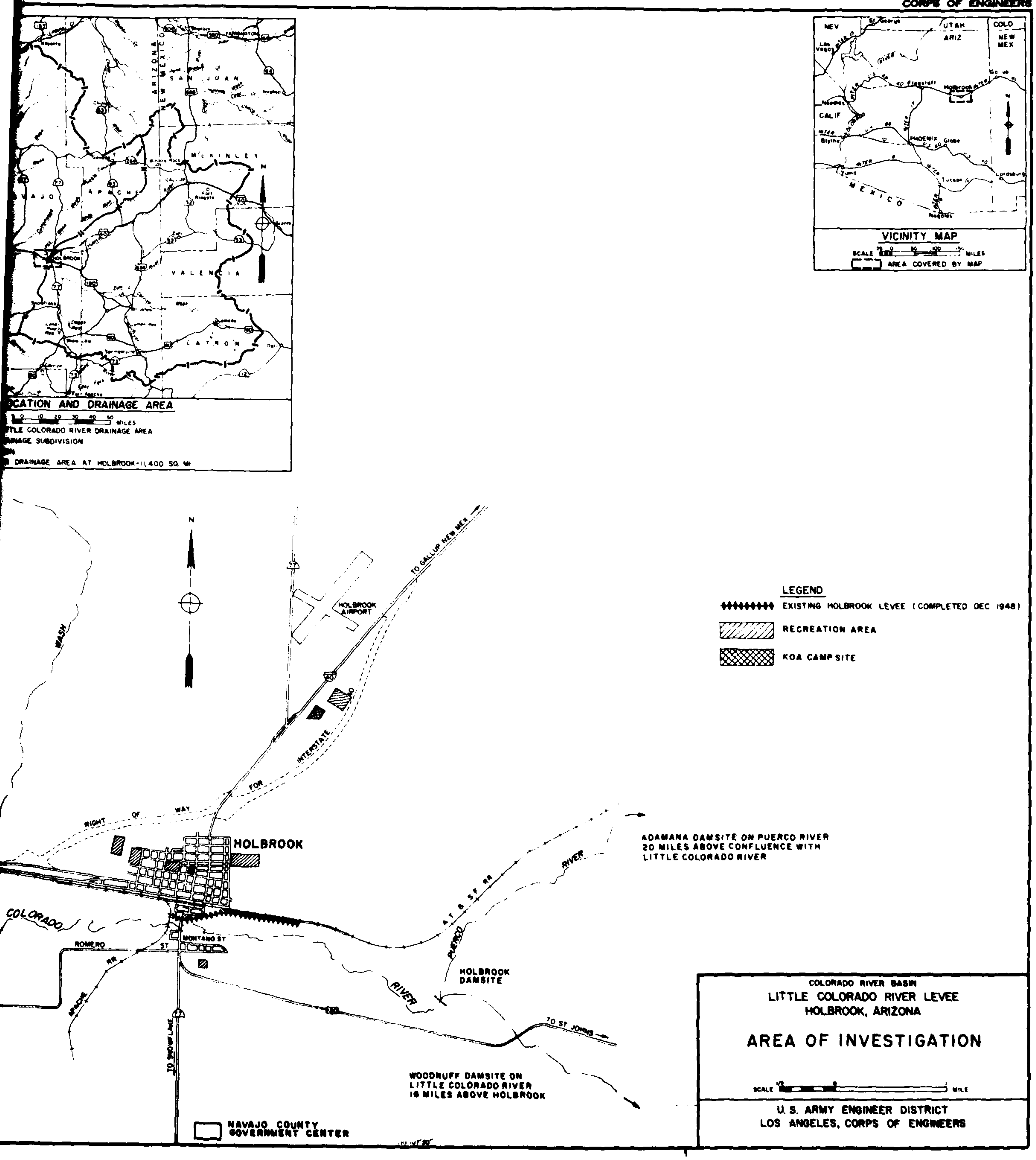
Engineering

89. Engineering constraints include the inability to find viable damsites and to implement flood plain management measures that will adequately provide for large sediment flows.

PLANNING OBJECTIVES

90. The principal objective of this study is to reduce the flooding potential along the Little Colorado River in the town of Holbrook. This study will also consider providing additional recreational facilities, specifically family picnic areas and bicycle trails, within the rights-of-way required for flood plain management measures. The study will evaluate methods of upgrading the currently substandard housing south of the Little Colorado River in Holbrook, and also consider methods of enhancing the diversity of riparian vegetation and related habitat within the Little Colorado River in Holbrook.

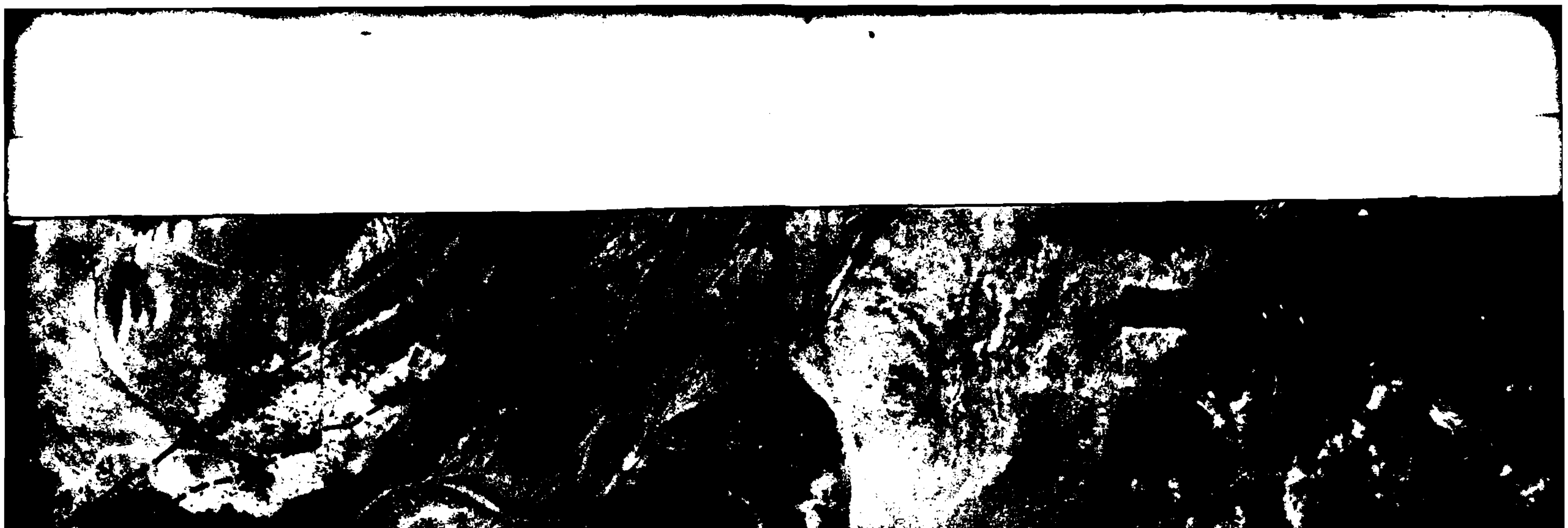

PROJECT LOCATION AND DRAINAGE AREA
SCALE 5 0 10 20 30 40 50 MILES
BOUNDARY OF LITTLE COLORADO RIVER DRAINAGE AREA
BOUNDARY OF DRAINAGE SUBDIVISION
PROJECT LOCATION
LITTLE COLORADO RIVER DRAINAGE AREA AT HOLBROOK-11,400 SQ MI
COCONINO
NAVAJO
APACHE
McKINLEY
VALENCIA
CATRON
YAVAPAI
GILA
SAN JUAN
ARIZONA
NEW MEXICO
HOLBROOK
GALLUP
FLAGSTAFF
N
34°57'30"
34°52'30"
110°12'30"
TO FLAGSTAFF
LEROUX
WASH
AT & SF RR
PENZANCE DIVERSION STRUCTURE
LITTLE
COLORADO
Flow
RIGHT OF WAY FOR
ROMERO ST
MONTANO ST
APACHE RR
TO SNOWFLAKE
NAVAJO COU
GOVERNMENT

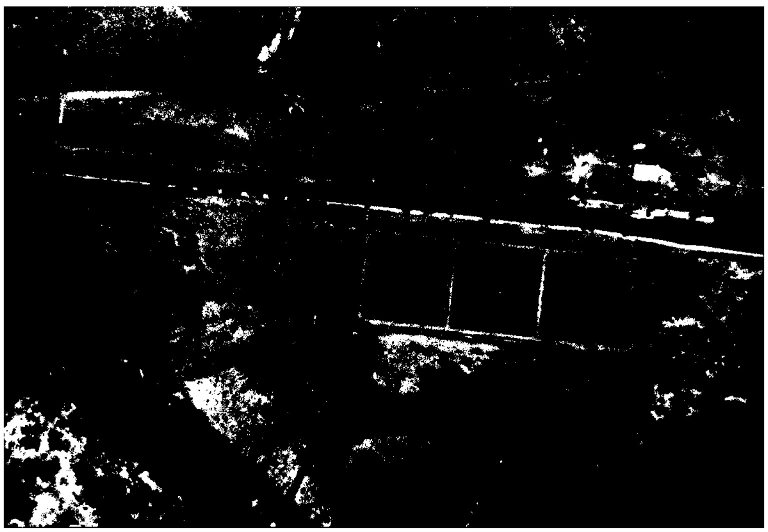

CORPS OF ENGINEERS
VICINITY MAP
NEV
UTAH
COLO
ARIZ
NEW MEX
CALIF
PHOENIX
MEXICO
AREA COVERED BY MAP
LOCATION AND DRAINAGE AREA
MILES
LITTLE COLORADO RIVER DRAINAGE AREA
DRAINAGE SUBDIVISION
DRAINAGE AREA AT HOLBROOK-11,400 SQ MI
SAN JUAN
MCKINLEY
APACHE
VALENCIA
CATRON
NAVAJO
LEGEND
EXISTING HOLBROOK LEVEE (COMPLETED DEC 1948)
RECREATION AREA
KOA CAMP SITE
TO GALLUP NEW MEX
HOLBROOK AIRPORT
RIGHT OF WAY FOR INTERSTATE
HOLBROOK
WASH
ADAMANA DAMSITE ON PUERCO RIVER
20 MILES ABOVE CONFLUENCE WITH
LITTLE COLORADO RIVER
PUERCO RIVER
A T & S F RR
COLORADO
ROMERO ST
MONTANO ST
APACHE RR
RIVER
HOLBROOK DAMSITE
TO ST JOHNS
TO SNOWFLAKE
WOODRUFF DAMSITE ON
LITTLE COLORADO RIVER
16 MILES ABOVE HOLBROOK
NAVAJO COUNTY
GOVERNMENT CENTER
COLORADO RIVER BASIN
LITTLE COLORADO RIVER LEVEE
HOLBROOK, ARIZONA
AREA OF INVESTIGATION
SCALE
MILE
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

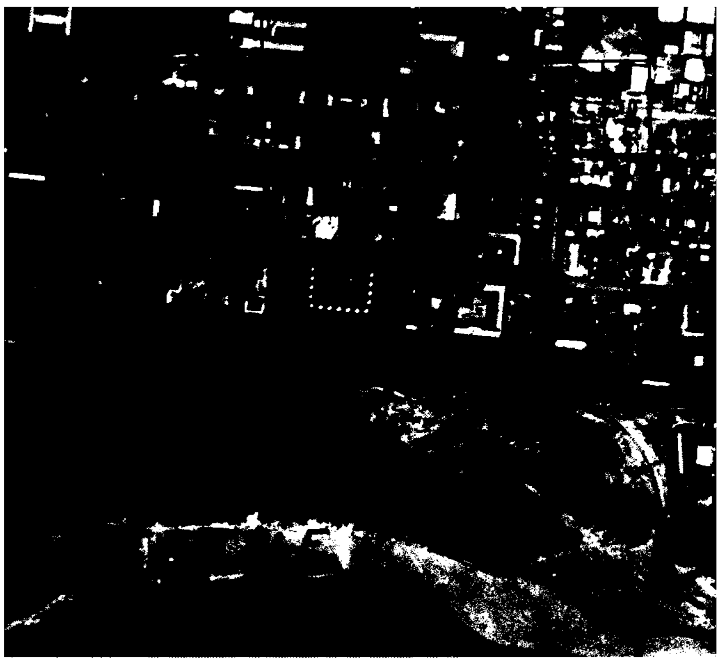
1

2


Flow
Flow







LEGEND

SPF
100 YEAR FLOOD
50 YEAR FLOOD

	DEPTH IN FEET	VELOCITY IN FEET PER SECOND
SPF	3.0	1.0
100 YR	2.0	to
50 YR	1.0	2.0

N

SCALE 800 0 800 FEET

LITTLE COLORADO RIVER
AT HOLBROOK ARIZONA

REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

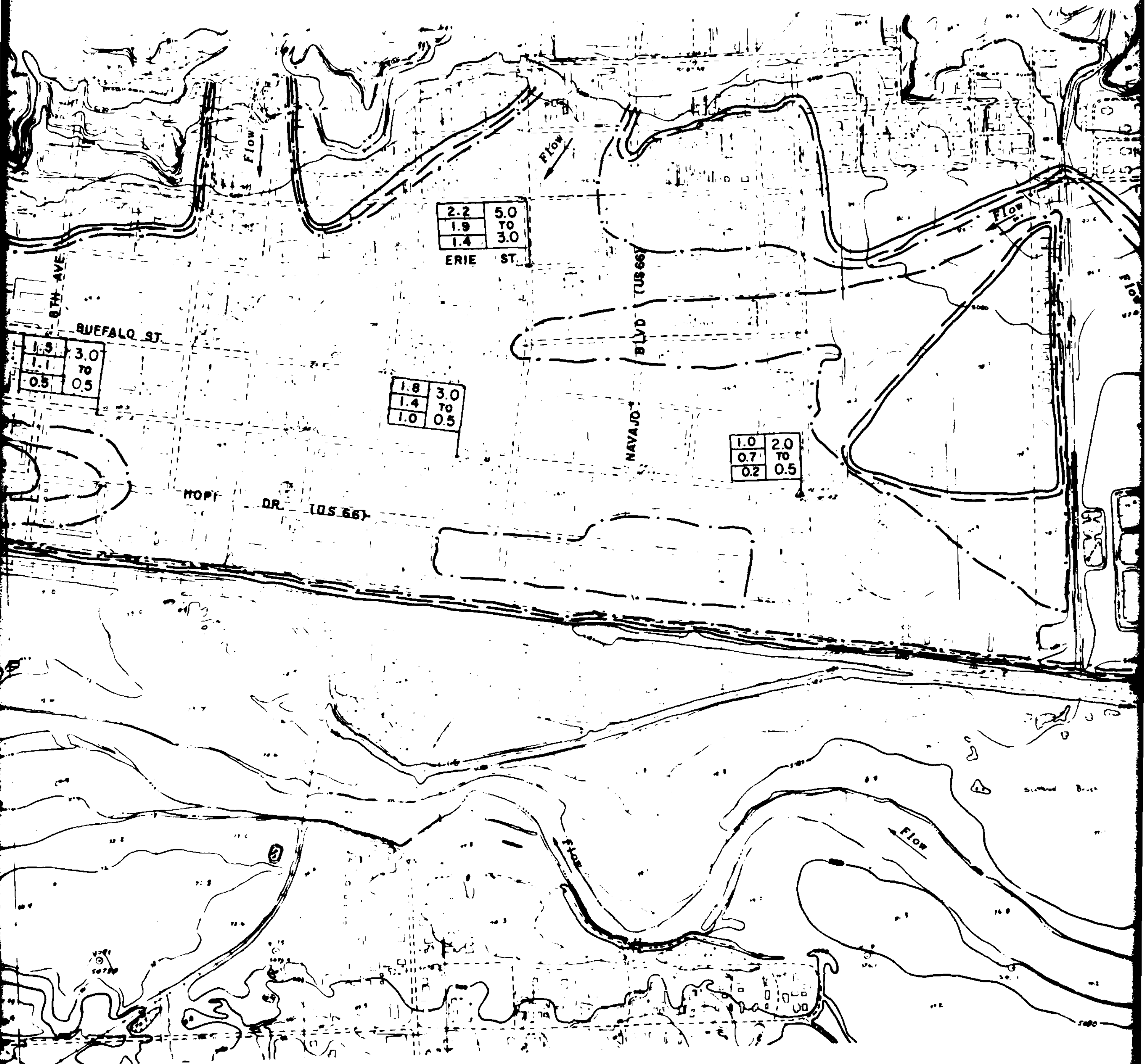
AREA SUBJECT TO FLOODING
BY THE LITTLE COLORADO RIVER
EXISTING CONDITIONS

U S ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

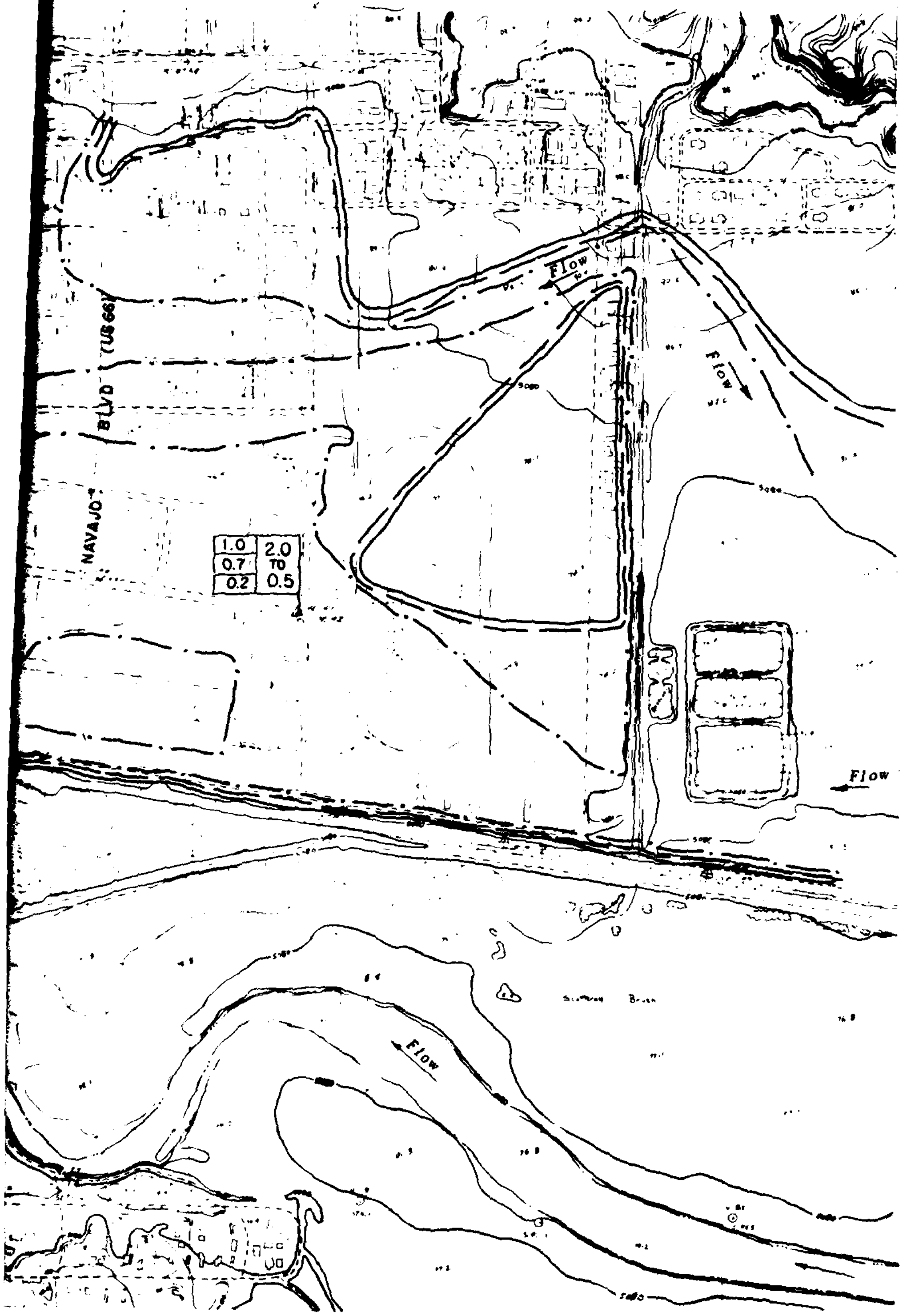
SHEET 2 OF 2

Plate A-2

Flow
12TH AVE
8TH AVE
BUFFALO
3.8
2.8
1.5
5.0 TO 3.0
1.4
1.1
0.7
3.0 TO 1.0
1.5
1.1
0.5
3.0 TO 0.5



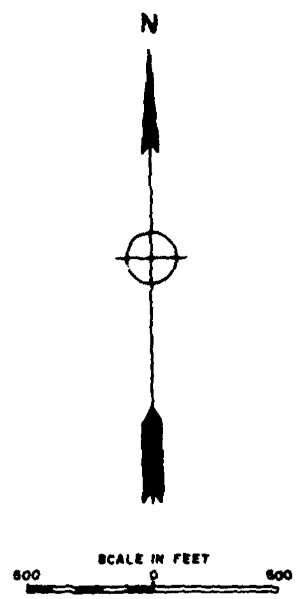
Flow
Flow
Flow
Flow
Flow
Flow
2.2 5.0
1.9 TO
1.4 3.0
ERIE ST.
8TH AVE
BUFFALO ST.
1.5 3.0
1.1 TO
0.5 0.5
1.8 3.0
1.4 TO
1.0 0.5
NAVAJO BLVD (US 66)
1.0 2.0
0.7 TO
0.2 0.5
HOPI DR. (US 66)



LEGEND

—— STANDARD PROJECT FLOOD
— — 100 YEAR FLOOD
— · — 50 YEAR FLOOD

	DEPTH IN FEET	VELOCITY IN FEET PER SECOND
SPF	3.0	2.0
100 YR	2.0	to
50 YR	1.0	1.0



LITTLE COLORADO RIVER
AT HOLBROOK, ARIZONA

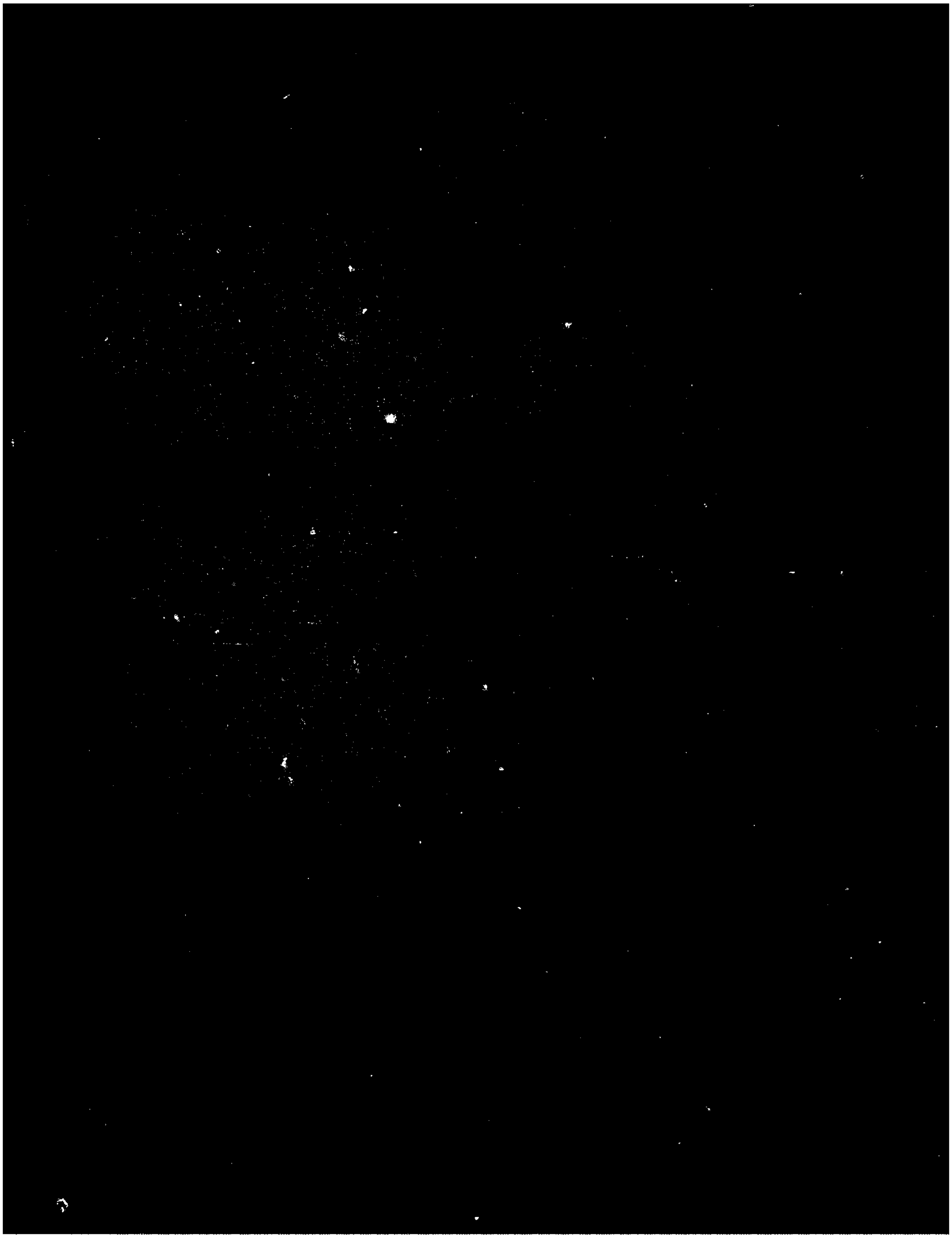
REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

AREA SUBJECT TO FLOODING

BY TRIBUTARIES OF THE
LITTLE COLORADO RIVER
EXISTING CONDITIONS

U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate A-3



Section B

FORMULATION, ASSESSMENT, AND EVALUATION OF DETAILED PLANS

Contents

CONTENTS (Continued)

CONTENTS (Continued)

Tables

Plates

Section B

FORMULATION, ASSESSMENT, AND EVALUATION OF DETAILED PLANS

1. Those plans carried forward from preliminary planning were studied in detail. The study of these plans, the single- and double-levee plans, and the floodproofing plan, is described in the following paragraphs. A description, impact assessment, and implementation requirements are included for each plan. A summary "System of Accounts," a description of the plan which maximizes economic efficiency, and a description of the plan which maximizes contributions to environmental quality are presented. Finally, a description of the process of choosing a selected plan is included. Plates B-1, B-4, and B-8 present conceptual drawings of the plans. The no-action alternative (base condition) is carried through detailed analysis as a base to compare alternatives.

SINGLE-LEVEE PLAN

Plan Description

2. The single-levee plan would include the following features (see plate B-1):

- The existing north levee would be reconstructed. The levee would be raised and extended upstream and downstream. The maximum levee height would be about 22 feet above existing ground. Most of the levee upstream from the Apache Railroad would be from 18 to 22 feet high. Downstream from the railroad bridge the maximum height would be about 13.5 feet, with most of the levee 12 feet high or lower. The levee would extend from a point about 6,800 feet upstream from the Route 77 bridge to a point about 12,000 feet downstream from the bridge, ending just upstream from Leroux Wash. The levee would be designed to provide standard project flood (SPF) protection (107,000 cubic feet per second) from flows in the Little Colorado River to development on the north side of the river.

- The existing Apache Railroad bridge would be removed and replaced with a similar bridge designed to pass the standard project flood.

- The State Route 77 bridge would remain in place. The decision to leave the bridge in place resulted because of a request from local interests. An economic analysis showed that leaving the bridge in place was superior to reconstructing the bridge, even though somewhat greater levee heights would be required because of hydraulic uncertainties with the bridge in place. Replacing the existing brige and the utility lines it carries with a

similar structure that would withstand a standard project flood would add about $900,000 to project costs. The existing bridge is obsolete as a state highway bridge and if destroyed would probably not be replaced in its present location. Therefore, no benefits for advance replacement of the bridge can be claimed. A small indeterminate benefit would be derived by protecting the utility lines from destruction by flood, however, the utilities could be repaired or replaced and protected at a stubstantially lower cost as need arises in the future. The existing miter gates in the north levee would be replaced by larger gates.

- The City of Holbrook has excavated and maitained a low-flow channel extending from near the Puerco River confluence downstream to a point near the Penzance diversion structure. The existing channel dimensions range from almost 80 feet to over 100 feet wide and from 3 to 5 feet deep. This channel would be reconstructed to a consistent minimum botttom width of 80 feet, and a minimum depth of 4 feet, having slopes 3 horizontal to 1 vertical. The low-flow channel would enhance movement of sediment through the project area during smaller flows and would also function as a pilot channel in directing larger flows and restricting meanders.

- To insure that deposition caused by vegetative growth does not reduce flow capacity significantly in the future a cleared strip 1,0000 feet wide and 15,540 feet in length would be established and maintained. The strip would extend from the upstream limit of the project to about 6,700 feet downstream of the railroad bridge. The cleared strip would utilize the path of the existing natural and low-flow channels as much as possible to minimize environmental damage. Future vegetative growth in the cleared strip would be limited to a height of 3 feet, but existing cottonwood trees would be allowed to remain.

- A 59-acre ponding area would be required to conrol interior drainage (tributary) flows emanating from two drainage areas located east and north of Holbrook. Runoff from these drainages flow southward and westward to coalesce just east of the old Navajo County Fairgrounds on the east edge of town where a small ponding area now exists behind the Santa Fe Railway embankment and the existing Corps of Engineers Levee, which are contiguous structures in this reach. A pond adequate to store the 100-year (1-percent-chance) flood volume from the two tributary areas would be formed by excavating the area to an average depth of about 4 feet below existing general ground surface. This pond would be drained by an existing double 4- by 4-foot culvert, including flap gates through the railroad embankment and levee. The culvert would be modified as required during construction of the north levee.

- Acquisition of rights-of-way including 23 acres for the north levee, 59 acres for the low-flow channel and cleared strip, 59 acres for the north-side ponding area, and 70 acres in the evacuation area south of the river.

- In addition to rights-of-way for construction, a permanent easement would be required for the entire riverbed from just below the Puerco River confluence to just below the Leroux Wash confluence. The easement would be designated as a floodway and would permit access for maintenance purposes. The easement would cover about 1,027 acres (pl. B-1), including 232 acres over which an existing easement was acquired for the existing project upstream from the Apache Railroad Bridge.

- Construction of a levee on the north side of the river to control a standard project flood would cause south-side water surfaces to increase about 0.5 foot and 3 feet, respectively, during the 100-year and standard project floods. Flood damages on the south side, without additional protective measures, would be increased $27,000 during the 100-year flood and $176,000 during a standard project flood. Average annual damages on the south side would be increased by $2,000 a year. In order to mitigate induced flood damages, to eliminate recurrent flooding of the south side with the attendant damages, adverse social impacts, and personal danger to the residents, and to take advantage of an opportunity to upgrade substandard housing conditions of south-side residents, about 57 residences and 10 businesses on the south side of the Little Colorado River which are located below the design water surface (3 feet below the top of the north levee) would be relocated outside the post-project flood plain. Plate B-1 shows the area to be evacuated. Most of the residences between the river and Romero Street are substandard and would require replacement with "decent, safe, and sanitary" housing in accordance with the "Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970." These residents would therefore qualify for supplemental housing payments over and above the market value of their existing homes in accordance with the act.

- Utility relocations consisting of relaying short reaches of existing water, gas, and oil lines and a telephone cable. These lines are hung on the Route 77 bridge. A couple of power poles might have to be reset.

- Recreational development would be included with the plan and would consist of a 3.7-mile-long bike trail located on the paved service road of the north levee and a 5 acre picnic area located in the north-side ponding area. The evacuated area on the south side could be an alternative site for the picnic area (see plate B-8). The bike trail would include 2 wooden shade structures with drinking fountains for rest stops. Appropriate

landscaping for the trail would be provided as part of the beautification plan for the north levee. The picnic area would include 10 picnic tables with shade structures and cooking units. Play equipment, open grass areas, and sanitation facilities would be provided. The picnic units would be raised to above the 20-year flood level. Floatable equipment would be anchored. Sanitation facilities would be protected to the 100-year flood level. Landscaping with trees, shrubs, and grass would be included in the picnic area.

Impact Assessment

3. The following paragraphs identify the impacts that would result from implementation of the single-levee plan.

4. NATIONAL ECONOMIC DEVELOPMENT. National economic development (NED) impacts include the first cost, annual operation and maintenance costs, and annual benefits. The first cost of this plan is estimated at $9,811,000 (September 1979 prices). The annual operation and maintenance costs would be $54,000. The total annual costs of the project, including interest and amortization on first costs (7-1/8--100 years) and operation and maintenance, are $713,000. The annual costs exclude interest and amortization on first financial costs of $570,000 for supplemental housing payments as these payments are considered to accrue intangible benefits equal to the costs (ER 1165-2-117).

5. The annual benefits for the single-levee plan could be as follows:

Benefits
Single-levee plan
100 yrs--7-1/8%

Flood damage reduction	$1,574,000
Reduction in insurable losses	10,000
Reduction in emergency costs	10,000
Employment	4,000
Recreation	25,000
Total	$1,623,000

6. The NED benefit-cost ratio would be 2.3 to 1.

6A. Evacuation of the south side is not justified on a last added increment basis (B/C=0.12), but is considered necessary to provide a solution to a severe existing social problem that would be made somewhat worse by construction of a north-side levee. (See "SOCIAL EFFECTS" below.) Construction of the south-side levee was treated as an integral part of the overall project for purposes of economic evaluation.

7. ENVIRONMENTAL EFFECTS. The single-levee plan would disturb approximately 210 acres of undisturbed riparian and 155 acres of disturbed riparian and non-riparian habitat. Clearing the 1,000-foot-

wide strip would destroy about 210 acres of dense phreatophytic growth. Construction of the north levee would destroy an estimated 25 acres of transitional riparian and marginal upland (disturbed) habitat. About 80 percent of the north levee site consists of moderately open stands of salt cedar with an occasional intermixing of cottonwood trees less than 20 feet tall. Dense stands of cottonwoods (hundreds to thousands) are adjacent to the proposed north levee alinement but would not be affected by levee construction. The remaining 20 percent of the area consists of an existing road paralleling the railroad bed near the sewage settling ponds. In this area, impacted vegetation would consist mostly of Russian thistle, locoweed, and grasses.

8. About 5 acres of disturbed upland habitat on the backside of the existing north levee and about 60 acres in the ponding area would be further disturbed during construction.

9. Approximately 65 acres of disturbed riparian habitat in the riverbed would be disrupted by construction and maintainenance of the low-flow channel and cleared strip.

10. Evacuation of the south side would allow 70 acres of disturbed habitat to revert to open space uses.

11. SOCIAL EFFECTS. The single-levee plan would eliminate the threat of loss of life, injury, and disease from floodflows on the Little Colorado River. Flood depths of up to 6 and 8 feet would be common under without project (base) conditions for the 100-year and standard project floods, respectively. (See pl. A-2.) Without the project floodflows overtopping the existing levee may cause failure of the levee resulting in sudden inundation of the City of Holbrook. With the project the City would be protected from floodflows up to and including the SPF (about the 1,000-year flood) on the Little Colorado River. (See pl. B-2.) Although flooding would continue to occur from tributaries north of town maximum depths in developed areas of 1.9 and 2.0 feet for the 100-year and SPF floods would not cause a threat comparable to that which currently exists. The maximum depths would occur only on steep slopes where flows emanate from canyon mouths and at Erie Street between Fourth and Sixth Avenues where two small stream (Streams A and B, Plate F-20, Section F of the Technical Appendix) coalesce. Over the remainder of the tributary flood plain, SPF depths would not exceed 1.5 feet and 100 year depths would not exceed 1.0 feet. Flooding between Navajo Boulevard and the ponding area would be eliminated up to the 100-year flood and reduced for larger floods. (See pl. B-3.) Reduction of the flood threat would reduce and in many cases eliminate the necessity for purchasing flood insurance, lessening that financial burden upon residents and businesses currently subject to flooding. The resulting financial savings and increase in security could lead to an increase in the quality of life in Holbrook. The present threat of loss of life, injury, disease, and social disruption on the south side affects about 57 families, mostly black and poor. Although the number of people threatened on the south side is far less

than on the north side, the threat is no more acceptable. The threat can be expected to grow with future sedimentation and would be increased somewhat by construction of a north-side levee to control the standard project flood. Construction of the north levee would cause 100-year and standard project flood water surfaces to rise by 0.5 foot and 3 feet, respectively. Flow velocities would be increased only slightly by the increased depths. Under the single-levee plan, the problems of the already existing untenable socil risks and induced flood damages on the south side would be resolved by permanent evacuation of existing development up to the design water surface.

12. The single-levee plan would require the relocation of 57 households and 10 businesses from south of the river to higher ground. The design water surface profiles were determined by increasing the computed water surface elevations (with future sediment allowances) by an additional 3.0 feet upstream from the highway bridge to account for the indeterminable effect of the bridge on major floodflows. Downstream from the highway bridge the computed values represent the design water surface elevations.

13. The low-income community that would be affected by the relocations is composed largely of substandard housing. The residents are mostly black and poor. The plan would require the virtual destruction of this community. However, the plan would also provide an opportunity to improve housing conditions for the people displaced. The "Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970" provides for supplemental payments of up to $15,000 to homeowners living in their homes and up to $4,000 foe renters. These payments would be made in addition to the fair market value of the property acquired. Supplemental payments would be paid so that persons who occupy substandard housing may acquire decent, safe, and sanitary housing if replacement in kind would be substandard. Although upgrading of housing conditions for people displaced by this plan would be a social benefit, some adverse effects could also result. Many of the people who would be displaced would prefer to stay in their present neighborhood rather than move, despite the opportunity for improved housing. This sentiment was expressed at a public meeting. Because supplemental payments are limited, relocations may cause a financial burden on the people relocated if the payments are not adequate to purchase replacement housing.

14. The families to be relocated probably could not afford a significant incrase in rent or mortgage payments. Even with the completion of units 3 and 4 at the Cholla Powerplant, housing will probably be limited in the Holbrook area, and finding replacement housing could be difficult. Construction of new housing as part of the project might be required. If adequate rental units were not available at the time of project implementation, renters could present a special problem. The city would probably be very reluctant to construct and administer new rental housing. The number of relocations involved in implementing the single-levee plan would undoubtedly cause inflationary pressure on the Holbrook housing market. At the same time the shortage of housing would probably require the use of housing costing more than

the people relocated could afford to pay, even with the supplemental payments required by the 1970 Act. This situation could result in some of the relocated homeowners eventually losing their homes. The long-term effect on renters is impossible to assess.

15. Other social effects of the single-levee plan would include a short term increase in noise during construction. The north levee, at a maximum height of 22 feet aboveground on the landward side, would impair views of the river from much of the city. However, existing levee, railroad embankment, and associated development currently obstruct the view, although to a lesser extent.

16. REGIONAL DEVELOPMENT. Regional development effects of the single-levee plan would include positive short-term increases in employment. This plan would require approximately 220 person-weeks of unskilled labor, with 12 laborers employed during peak construction.

17. During the evacuation of the south side the local tax base will be reduced. However, the increased demand for housing, supplemental housing payments, and reduced flood threat should increase the tax base in the long run.

18. The non-Federal financial share of project first costs, including a 5 percent share of first costs assigned to the state, would be $2,478,000 (September 1979 prices) in accordance with the President's water policy. The cost to Holbrook for flood control would be $1,946,000 (20 percent of total first costs); Holbrook's recreation costs would be $41,500 (50 percent of total first costs). The State of Arizona is authorized by State Senate Bill 1104 to reimburse up to 50 percent of non-Federally supported costs for lands, easements, and rights-of-way for a Federal flood control project, an amount estimated at $973,000. This state help would reduce Holbrook's flood control contribution to $973,000. However, in accordance with the President's policy, the state would be required to contribute 5 percent of the first cost of the project, an amount estimated at $490,200 ($486,000 for flood control; $4,200 for recreation). The city of Holbrook would operate and maintain the project at an annual cost of $54,000 ($44,000 for flood control; $10,000 for recreation).

19. WILDLIFE MITIGATION REQUIREMENTS. Mitigation requirements for the single-levee plan were established through consultation with U.S. Fish and Wildlife Service (see appendix 2 of this report, the U.S. Fish and Wildlife Service "Draft Coordination Act Report"). These requirements were established to minimize project impacts on fish and wildlife resources while maintaining the functional integrity of the project. Following are mitigation features of the plan.

- On each side of the low-flow channel, and about midway between the low-flow channel and the outer edge of the cleared strip, a 30-foot wide strip would be left uncleared. This strip would begin about 300 feet downstream of the Apache Railroad bridge and extend downstream to the end of the cleared strip. The

purpose of the uncleared strips would be to mitigate losses of wildlife cover which allows movement from river bank and upland areas to the river.

- Locating the uncleared strips midway between the channel and the edges of the cleared strip would greatly reduce the total distance from cover for wildlife migrating from upland areas to the river bank.

- About 500--1,000 Fremont cottonwood and Goodding willow trees from 3 to 5 feet high would be planted about 25 feet south of the toe at the north levee and in stream meanders downstream of the Apache Railroad bride. None of this planting would be accomplished inside the cleared strip.

- The cleared strip would be planted with broadcast stolons of saltgrass and alkalid sacaton. The cleared area would be mowed in strips. These grasses would provide diversified habitat, and would inhibit growth of larger, flow impeding growth. To prevent disturbing the entire area each year, a program of mowing a strip approximately one-third of the total area each year would be established. This selective mowing would meet the requirements of limiting the height of growth to 3 feet. This rotational mowing plan would also help the city to balance its yearly operation and maintenance expenditures.

- No additional real estate interests are required for mitigation.

Evaluation and Trade-Off Analysis

20. The following section presents the plan's fulfillment of the planning objectives and response to evaluation criteria.

21. PLANNING OBJECTIVE FULFILLMENT. The following paragraphs describe how the single-levee plan fulfills the planning objectives established earlier in the study.

22. Reduction of Flooding. This plan would reduce flooding from the Little Colorado River up to the standard project flood. Construction of the ponding area for interior drainage would reduce the potential for flooding in Holbrook caused by tributaries north and east of the city.

23. Recreation. Construction of a bike trail and picnic areas would be part of this plan and would enhance recreational opportunities in Holbrook.

24. Housing. Evacuation of the south side would provide an opportunity to improve housing for 57 families, about half of which are homeowners. Although housing availability is uncertain at this time there is no doubt that the plan would increase the quality of housing in Holbrook.

25. Diversifying Vegetation. Clearing salt-cedar, planting grasses, and planting cottonwood and willow would help to diversify the vegetation in the Little Colorado Riverbed.

26. EVALUATION CRITERIA. A discussion of how this plan meets the evaluation criteria of acceptability, completeness, effectiveness and efficiency, continuity, certainty, geographic scope, reversibility, and stability follows.

27. Acceptability. The single-levee plan is acceptable to most of the population of Holbrook. Meetings with the City of Holbrook indicate a reluctance to prefer this plan because of the number of relocations involved. The families that would be relocated are somewhat reluctant to accept this plan, because they are unsure of the availability of alternative housing. Some of the families that would be relocated have very low incomes and feel that they could not afford any increase in housing cost, even though improved housing would be provided. The single-levee plan is unacceptable to these people. Without state aid, funding requirements could make this plan unacceptable to locals.

28. Completeness. Continued maintenance of the plan elements would be required. No other investments would be required to achieve the outputs of the plan.

29. Effectiveness and Efficiency. This plan is the least costly way of providing the outputs and meeting the planning objectives above. The benefits-cost ratio is 2.3 to 1.0.

30. Certainty. It is uncertain whether implementation of this plan would meet the objective of improved housing because of problems previously discussed. It is likely that the plan would achieve the planning objectives of reduced flood damages, increased recreational opportunities, and diversified vegetation.

31. Geographical Scope. Except for the costs to be borne by the general taxpayer (75 percent of total project first cost) and the State of Arizona (at least 5 percent of total first cost) the effects of the project would be limited to the study area of Holbrook and its immediate vicinity.

32. Reversibility. Once this plan is built, the resources would be committed and there would be little ability to reverse the effects of the plan without incurring additional investment.

33. Stability. This plan accommodates a range of alternative futures. The plan would discourage evacuation of the north side pre-project flood plain and would, in fact, encourage renovation and upgrading of existing structures in that area. The south side flood plain would be evacuated in perpetuity.

Implementation Responsibilities

34. The following paragraphs discuss cost apportionment for the single-levee plan and the separation of responsibilities between Federal and non-Federal interests.

35. COST APPORTIONMENT. Cost apportionment between Fedeal and non-Federal entities is based on existing legislation and policy. Current policy includes cost-sharing proposed by President Carter in his June 1978 water policy message to Congress. All costs are based on September 1979 price levels. The total first cost of the project is estimated at $9,811,000 ($9,728,000 for flood control; $83,000 for recreation). Annual operation and maintenance costs are estimated at $54,000 ($44,000 for flood control; $10,000 for recreation).

36. Federal. The Federal cost for the single-levee plan would include 75 percent of total first cost for flood control. The Federal Government would also pay 45 percent of recreation facilities cost.

37. Non-Federal. The State of Arizona would pay 5 percent of total first costs for flood control and recreation. The City of Holbrook would pay 20 percent of first flood control costs and 50 percent of recreation facilities costs. Under existing State law, Holbrook could be reimbursed by the State for a portion of its costs. The city would also be responsible for operation and maintenance of the project at an estimated cost of $54,000 ($44,000 for flood control and $10,000 for recreation).

38. The following tables show cost apportionment for the single levee plan under the President's water policy and under existing law.

TABLE B-1a

CALCULATION OF MITIGATION COST APPORTIONMENT
Single Levee Plan

Flood Control	Federal	Non-Federal	Total
Construction	4,181,000	-0-	
Lands & Relocation	2,154,000	3,308,000	
Operation & Maintenance (capitalized)	-0-	617,000	
Total	6,335,000	3,925,000	10,260,000

Contribution of local interests towards mitigation

$$= \frac{3,925,000}{10,260,000} \times 85,000 = 33,000$$

TABLE B-1

Cost Apportionment
Single-Levee Plan

Item	First Cost	Federal Share	Non-Federal Share
Flood Control			
Construction	$4,181,000	$ 4,181,000	$ 0
Lands and relocations	5,462,000	2,154,000	3,308,000
Wildlife mitigation	85,000	52,000	33,000
Total (traditional cost sharing based on existing law)	$9,728,000	$ 6,387,000	$ 3,341,000
Adjustment for Federal reimbursement for costs in excess of 20 percent of flood damage reduction costs	—	$+3,566,000	$-3,566,000
Adjusted subtotals	$9,728,000	$ 7,782,000	$ 1,946,000
Adjustment for 5 percent non-Federal (State contribution) of total first costs	—	$ -486,000	$ +486,000
Adjusted totals--flood control	$9,728,000	$ 7,296,000	$ 2,432,000
Recreation (traditional cost sharing	$ 83,000	$ 41,500	$ 41,500
Adjustment for 5 percent non-Federal (State contribution) of total first cost	—	$ -4,200	$ +4,200
Adjusted totals--recreation	$ 83,000	$ 37,300 (say $37,000)	$ 45,700 (say $46,000)
Adjusted project first costs	$9,811,000	$ 7,333,000	$ 2,478,000

39. SEPARATION OF RESPONSIBILITIES. Following is a summary of the division of implementation responsibilities between Federal and Non-Federal interests.

40. Federal. In addition to its financial responsibility, the Federal Government would design, prepare detailed plans, and administer contracts for construction of the project.

41. Non-Federal. In addition to financial responsibilities, the City of Holbrook would be responsible for the actual acquisition of rights-of-way and the performance of the relocations of utilities, highways, and structures. They would be responsible for actual performance of project operation and maintenance. Local interests would also be required to prescribe and enforce regulations to prevent obstruction or encroachment on the project's flood carrying capacity for the proper functioning of the project.

DOUBLE-LEVEE PLAN

42. The double-levee plan is similar to the single-levee plan in some respects and differs in others. In the following plan description, the elements that are the same or virtually the same as the single-levee plan are marked with a + sign.

Plan Description

43. The double-levee plan would include the following features (see plate B-4):

- \+ The existing north levee would be reconstructed. The levee would be raised and extended upstream and downstream. The maximum levee height would be about 23 feet above existing ground. Most of the levee upstream from the Apache Railroad would be from 18 to 23 feet high. Downstream from the railroad bridge the maximum height would be about 13.5 feet, with most of the levee 12 feet high or lower. The levee would extend from a point about 6,800 feet upstream from the Route 77 bridge to a point about 12,000 feet downstream from the bridge, ending just upstream from Leroux Wash. The levee would be designed to provide standard project flood (SPF) protection (107,000 cubic feet per second) from flows in the Little Colorado River to development on the north side of the river.

- Construction of a levee on the north side of the river to control a standard project flood would cause south side water surfaces to increase about 0.5 foot and 3 feet, respectively, during the 100-year and standard project floods. Flood damages on the south side, without additional protective measures would be increased $27,000 during the 100-year flood and $176,000 during a standard project flood. Average annual damages on the south side would be increased by $2000 a year. In order to mitigate induced flood damages, to eliminate recurrent flooding

of the south side with the attendant damages, adverse social impacts, and personal danger to the residents, and to take advantage of an opportunity to upgrade substandard housing conditions of some south-side residents. A levee would be constructed on the south side of the river. This levee would be a maximum of 23 feet high and would extend from the Apache Railroad embankment about 3,400 feet eastward and then hook southward to higher ground (total length = 5,000 feet). Construction of the levee would require relocation of nine substandard residences and two businesses (this compares with relocation of 57 residences and 10 businesses for the single-levee plan).

- The existing Apache Railroad bridge would be removed and replaced with a similar bridge designed to pass the standard project flood.

- The State Route 77 bridge would remain in place. The decision to leave the bridge in place resulted because of a request from local interests. An economic study showed that leaving the bridge in place was slightly superior to reconstructing the bridge, even though somewhat greater levee heights would be required because of hydraulic uncertainties with the bridge in place. The existing miter gates in the north levee would be replaced by larger gates, and a miter gate would be included in the south levee. Replacing the existing bridge and the utility lines it carries with a similar structure that would withstand a standard project flood would add about $250,000 to project costs. The existing bridge is obsolete as a state highway bridge and if destroyed would probably not be replaced in its present location. Therefore, no benefits for advance replacement of the bridge can be claimed. A small indeterminate benefit would be derived by protecting the utility lines from destruction by flood, however, the utilities could be repaired or replaced and protected at a substantially lower cost as need arises in the future.

- The City of Holbrook has excavated and maintained a low-flow channel extending from near the Puerco River confluence downstream to a point near the Penzance diversion structure. The existing channel dimensions range from almost 80 feet to over 100 feet wide and from 3 to 5 feet deep. This channel would be reconstructed to a consistent minimum bottom width of 80 feet, and a minimum depth of 4 feet, having side slopes 3 horizontal to 1 vertical. The low-flow channel would enhance movement of sediment through the project area during smaller flows and would also function as a pilot channel in directing larger flows and restricting meanders.

- To insure that vegetative growth does not reduce flow capacity significantly, a cleared strip 1,000 feet wide and 15,340 feet in length would be established and maintained. The strip would

extend from the upstream limit of the project to about 6,700 feet downstream of the railroad bridge. The cleared strip would utilize the path of the existing natural and low-flow channels as much as possible to minimize environmental damage. Future vegetative growth in the cleared strip would be limited to a height of 3 feet, but existing cottonwood trees would be allowed to remain.

- A 59-acre ponding area would be required to control interior drainage (tributary) flows emanating from two drainage areas located east and north of Holbrook. Runoff from these drainages flow southward and westward to coalesce just east of the Old Navajo County Fairgrounds on the east edge of the city where a small ponding area now exists behind the Santa Fe Railway embankment and the existing Corps of Engineers Levee, which are contiguous structures in this reach. A pond adequate to store the 100-year (1-percent-chance) flood volume from the two tributary areas would be formed by excavating the area to an average depth of about 4 feet below the existing general ground surface. This pond would be drained by an existing double 4-foot by 4-foot flap gated culvert through the railroad embankment and levee. The culvert would be modified as required during construction of the north levee.

- Acquisition of rights-of-way including 23 acres for the north levee, 59 acres for the low-flow channel and cleared strip, 59 acres for the north-side ponding area, and 20 acres for the south levee and south side interior drainage channel. These 20 acres compare with 70 acres required for the evacuation area in the single-levee plan. Relocation of 9 sub-standard residences and 2 businesses would be required for construction of the south levee. The residences are substandard and would require replacement with "decent, safe, and sanitary 11 housing in accordance with the "Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970." These residents would, therefore, qualify for supplemental housing payments over and above the market value of their existing homes in accordance with the act.

- In addition to rights-of-way for construction, a permanent flowage easement would be required for the entire riverbed from just below the Puerco River confluence to just below the Leroux Wash confluence. The easement would be designated as a floodway and would permit access for maintenance purposes. The easement would cover about 1,027 acres (pl. B-4), including 232 acres over which an existing easement was acquired for the existing project upstream from the Apache Railroad Bridge.

- Utility relocations consisting of relaying short reaches of existing water, gas, and oil lines and a telephone cable. These lines are hung on the Route 77 bridge. A couple of power poles might have to be reset.

- Recreational development would be included with the plan and would consist of a 3.7-mile-long bike trail located on the paved service road of the north levee and a 5-acre picnic area located in the north side ponding area. The evacuated area on the south side could be an alternative site for the picnic area (see plate B-8). The bike trail would include 2 wooden shade structures with drinking fountains for rest stops. Appropriate landscaping for the trail would be provided as part of the beautification plan for the north levee. The picnic area would include 10 picnic tables with shade structures and cooking units. Play equipment, open grass areas, and sanitation facilities would be provided. The picnic units would be raised to above the 20-year flood level. Floatable equipment would be anchored. Sanitation facilities would be protected to the 100-year flood level. Landscaping with trees, shrubs, and grass would be included in the picnic area.

Impact Assessment

44. NATIONAL ECONOMIC DEVELOPMENT. National economic development (NED) impacts include the first cost, operation and maintenance costs, and annual benefits. The first cost of this plan is estimated at $9,634,000 (September 1979 prices). The annual operation and maintenance costs would be $59,000. The total annual costs of the plan, including interest and amortization on first costs (7-1/8%—100 years) and operation and maintenance, but excluding the interest and amortization on supplemental housing costs ($11,000 per annum), are $735,000. The annual costs exclude interest and amortization on first financial costs for supplemental housing payments of $165,000. (ER 1165-2-117)

45. The annual benefits for the double-levee plan are:

Benefits
Double-levee plan
100 yrs—7-1/8%

Flood damage reduction	$1,587,000
Reduction in insurable losses (south side)	5,000
Reduction in emergency costs (south side)	2,000
Employment	4,000
Recreation	25,000
Total	$1,624,000

46. The NED benefit-cost ratio would be 2.2 to 1.

47. Construction of a levee on the south side is not justified on a last added increment basis (B/C=0.15), but is considered necessary to provide a solution to a severe existing social problem that would be made somewhat worse by construction of a north-side levee. (See "SOCIAL

EFFECTS" below). Construction of the south-side levee was treated as an integral part of the overall project for purposes of economic evaluation.

48. ENVIRONMENTAL EFFECTS. The double-levee plan would disturb approximately 210 acres of undisturbed riparian habitat and 175 acres of disturbed riparian and non-riparian habitat. Environmental effects of the double-levee plan would be similar to the single-levee plan except:

- The south-levee and interior drainage channel would affect about 20 acres that have limited natural growth. A locally constructed flood protection embankment south of the river has highly disturbed the area and eliminated most natural wildlife habitat.

- Whereas the single-levee plan would allow 70 acres to revert to open space uses, the double-levee plan would not have this effect.

49. SOCIAL EFFECTS. Flood depths of up to 6 and 8 feet could be expected on both sides of the river under no action (base) conditions for the 100-year and standard project floods, respectively, on the Little Colorado River. The double-levee plan would eliminate this hazard and reduce the socially unacceptable threat of loss of life, injury, and disease in Holbrook. Overtopping could result in failure of the existing levee and sudden inundation of the city. The double-levee plan would eliminate this hazard for floods up to and including the standard project flood. (See pl. B-5.) Although local flooding can be expected to occur from tributaries north and east of the city, maximum flood depths of 2.0 and 1.9 feet for the SPF and 100-year floods would not pose a threat comparable to that which currently exists from flows on the Little Colorado River. (See pl. B-6.)

50. The present threat of loss of life, injury, disease, and social disruption on the south side affects about 57 families, most of whom are black and poor. Although the number of people threatened on the south side is far less than on the north side, the threat is no more acceptable. The threat can be expected to grow with future sedimentation and would be increased somewhat by construction of a north-side levee to control the standard project flood. Construction of the north levee would cause 100-year and standard project flood water surfaces to rise by 0.5 foot and 3 feet, respectively. Flow velocities would be increased only slightly by the increased depths. Under the double-levee plan, the problems of the aready existing untenable social risks and induced flood damages on the south side would be resolved by construction of a levee to protect south side development.

51. As compared to the single-levee plan, the double-levee plan would require the relocation of only 9 houses and 2 businesses rather than the relocation of 57 houses and 10 businesses required by the single-levee plan. This would reduce the opportunity to upgrade substandard housing. However, a limited opportunity would exist under

the double-levee plan and it would be more probable that adequate alternative housing would be available. The south levee would protect the south-side community and the reduction of the flood threat would encourage upgrading of the housing stock.

52. The levees would be a maximum of 23 feet high, and would impair views across the river.

53. REGIONAL DEVELOPMENT. The double-levee plan would require approximately 256 person-weeks of unskilled labor, with 16 laborers employed during peak construction.

54. The non-Federal financial share of project first costs, including a 5 percent share of first costs assigned to the state, would be $2,434,000 (September 1979 prices) in accordance with the President's water policy. The cost to Holbrook for flood control would be $1,910,000 (20 percent of total first costs); Holbrook's recreation costs would be $41,500 (50 percent of total first costs). The State of Arizona is authorized by State Senate Bill 1104 to reimburse up to 50 percent of non-Federally supported costs for lands, easements, and rights-of-way for a Federal flood control project, an amount estimated at $955,000. This state help would reduce Holbrook's flood control contribution to $955,000. However, in accordance with the President's policy, the state would be required to contribute 5 percent of the first cost of the project, an amount estimated at $482,200 ($478,000 for flood control; $4,200 for recreation).

55. The city of Holbrook would also be responsible to operate and maintain the project features at a cost of $59,000 annually ($49,000 for flood control; $10,000 for recreation).

Wildlife Mitigation Requirements

56. Mitigation requirements for the double-levee plan would be identical with the single-levee plan.

Evaluation and Trade-Off Anlaysis

57. PLANNING OBJECTIVE FULFILLMENT. The following paragraphs describe the degree to which the double-levee plan fulfills the planning objectives.

58. Reduction of Flooding. Same as single-levee plan except that development remaining in south side flood plain would be subject to flooding from floods in excess of the standard project flood.

59. Recreation. Same as single-levee plan.

60. Housing. Construction of south levee would require evacuation of 9 substandard houses. This would create an opportunity to provide safe and sanitary houses for these families through supplemental housing payments.

61. Diversifying Vegetation. Same as single-levee plan, except this plan would allow about 20 acres (as compared to 70 acres for the single-levee plan) to revert to open space uses.

62. EVALUATION CRITERIA. A discussion of how the double-levee plan meets the evaluation criteria follows.

63. Acceptability. This plan appears to be acceptable to the concerned publics, but acceptability is dependent upon state and/or county assistance toward funding the local cost share.

64. Completeness. Continued maintenance of the plan would be required. The plan is otherwise complete.

65. Effectiveness and Efficiency. This plan has an overall benefit-cost ratio of 2.2 to 1. Based on annual charges and the benefit-cost ratio, this plan is not quite as efficient as the single-levee plan.

66. Certainty. It is likely the plan will achieve the planning objectives and provide the outputs anticipated.

67. Geographical Scope. Except for Federal and State contributions for funding, project effects would be limited to the study area.

68. Reversibility. Once this plan is constructed, resources will be committed and there will be little ability to reverse the effects of the plan without further investment.

69. Stability. This plan accomodates a range of alternative futures.

Implementation Responsibilities

70. The following paragraphs discuss cost-apportionment for the double-levee plan and separation of responsibilities between Federal and non-Federal interests.

71. COST APPORTIONMENT. The total first cost of the project is estimated at $9,634,000 ($9,551,000 for flood control; $83,000 for recreation; September 1979 prices).

72. Federal. The Federal first cost for the double-levee plan would include 75 percent of total flood control cost. The Federal Government would also pay 45 percent of recreation cost.

73. Non-Federal. The State of Arizona would pay [illegible] percent of total first costs for flood control and recreation. The city of Holbrook would pay 20 percent of first flood control costs and 50 percent of recreation facility costs. Under existing state law,

Holbrook could be reimbursed by the state for a portion of its costs. Holbrook would be responsible for operation and maintenance of the project at an estimated annual cost of $59,000.

74. The following tables show cost apportionment for the double-levee plan under the President's water policy and under existing law.

TABLE B-2a

CALCULATION OF MITIGATION COST APPORTIONMENT
Double-Levee Plan

Flood Control	Federal	Non-Federal	Total
Construction	6,171,000	-0-	
Lands & Relocation	2,153,000	1,136,000	
Operations & Maintenance (capitalized)	-0-	687,000	
	8,324,000	1,823,000	10,147,000

Contribution of local interests towards mitigation

$$= \frac{1,823,000}{10,147,000} \times 91,000 = 16,000$$

TABLE B-2

COST APPORTIONMENT
DOUBLE-LEVEE PLAN

Item	First Cost	Federal Share	Non-Federal Share
Flood Control			
Construction	6,171,000	6,171,000	Ø
Lands and relocations	3,289,000	2,153,000	$ 1,136,000
Wildlife mitigation	91,000	75,000	16,000
Total (traditional cost sharing based on existing law)	9,551,000	8,399,000	1,152,000
Adjustment for Federal reimbursement for costs in excess of 20 percent of flood damage reduction costs	—	-758,000	+758,000
Adjusted subtotals	9,551,000	7,641,000	1,910,000
Adjustment for 5 percent non-Federal (State contribution) of total first costs	—	-478,000	+478,000
Adjusted totals—flood control	9,551,000	7,163,000	2,388,000
Recreation (traditional cost sharing)	83,000	41,500	41,500
Adjustment for 5 percent non-Federal (State contribution) of total first cost	—	-4,200	+4,200
Adjusted totals—recreation	83,000	37,300 (say 37,000)	45,700 (say 46,000)
Adjusted project first costs	9,634,000	7,200,000	2,434,000

75. SEPARATION OF RESPONSIBILITIES. A summary of the division of plan responsibilities follows.

76. Federal. Same as single-levee plan.

77. Non-Federal. Same as single-levee plan.

FLOODPROOFING PLAN

Plan Description

78. This nonstructural plan calls for floodproofing all structures on the north side of the river against the standard project flood (SPF). A design to floodproof to the 100-year flood was examined but it was rejected because the additional protection could be provided with only a 2-percent increase in first cost. Floodproofing for the south side was not considered feasible because of the condition and low value (less than the cost of flood proofing) of most of the buildings.

79. Two methods of flood proofing were assumed to be employed. Structures that would be flooded to depths of less than 2 feet were assumed to be protected with low walls around the building. Access openings would be sealed during times of flooding. Structures that would be flooded to depths of 2 feet or greater were assumed to be protected by raising them above the SPF water surface and placing them on cast-in place piers (see pl. B-7). A total of 791 structures would be flood proofed, including 580 single family residences. Mobile homes were not included in the structures to be floodproofed, since they could be moved easily outside the flood plain. Structures to be raised would be elevated an average of 7 feet. This plan would include architectural renderings, raising the structure, construction of a foundation and piers, and construction of suitable access structures (concrete stairs). Plumbing, electrical connections, ducts and other utilities would require replacement and insulation. Beautification and landscaping would also be necessary.

Impact Assessment

80. NATIONAL ECONOMIC DEVELOPMENT. The overall cost of this plan is estimated at $18,650,000 (September 1979 prices). Operation and maintenance costs were not estimated for this plan, because they would basically be the normal costs for maintaining a structure. Total annual costs for this plan, including interest and amortization of first costs are $1,423,000 (7-1/8 percent--40 years).

81. The floodproofing plan was analyzed over a 40-year period as this was felt to be the maximum remaining life of the structures. The annual benefits accruing to this plan would be as follows:

Benefits
Floodproofing plan
September 1979 prices
40 yrs—7-1/8%

Flood damage reduction		$1,159,000
Employment		49,000
	Total	$1,208,000

82. The NED benefit-cost ratio is .85 to 1. Floodproofing appeared to be economically feasible during preliminary planning, however, more refined analysis later showed this approach to be not economically justified. The plan was carried through detailed planning as a representative nonstructural plan.

83. ENVIRONMENTAL EFFECTS. This plan would have negligible environmental effects.

84. SOCIAL EFFECTS. The floodproofing plan would considerably reduce the threat of loss of life, injury, and disease from floodflows on the Little Colorado River and from tributaries (interior drainage) to the river originating north and east of the city. Because continued street and lawn flooding would continue, a threat to the safety and well-being of Holbrook citizens and tourists would remain. The socially unacceptable threat to south-side residents, discussed with the levee plans, would remain unabated. There would be no induced damages.

85. The threat of flood damage and injury to residents south of the river would remain with this plan.

86. There would be a disruption to general business activity in the city of Holbrook during construction of this plan. Approximately 606 families would be disturbed or displaced during construction. Of these, 26 families residing in mobile homes would be evacuated from the flood plain. The remaining families could possibly be housed in vacant motel and hotel rooms if construction occurred during the off-peak tourist season and was staged. This housing cost, however, was not considered in the benefit-cost ratio because it was considered a financial transfer payment from the homeowners or government to hotel and motel owners rather than an economic cost.

87. There would be an increase of noise during construction in populated areas.

88. Although preliminary plans call for landscaping and beautification costs, houses homogeneously placed about 7 feet above ground level could be an eyesore.

89. REGIONAL DEVELOPMENT. Construction of the flood proofing plan would provide a short term increase in employment. Each single family structure to be raised would require about 120 person-hours of unskilled labor. Approximately $1,260,000 of the total first cost of this alternative would be spent in the local labor force.

90. *Reducing the flood threat on development to be floodproofed* would increase the tax base for the city of Holbrook.

91. In accordance with Section 73 of the Water Resources Development Act of 1974 (Public Law 93-251) and President Carter's June 1978 water policy message to Congress, the Federal Government can participate in nonstructural flood control projects. However, because this plan is not economically justified the total first cost of $18.7 million would be borne by non-Federal interests.

Mitigation Requirements

92. No mitigation would be required for this plan.

Evaluation and Trade-Off Analysis

93. PLANNING OBJECTIVE FULFILLMENT. Following is a description of how the floodproofing plan fulfills the study's planning objective.

94. Reduction of Flooding. This plan would reduce flood damages from the SPF and larger floods on the Little Colorado River and tributaries in Holbrook. This plan would do nothing to solve flooding problems south of the river. Flooding in streets and lawns would continue to occur in Holbrook. Business and emergency costs would still be incurred due to flooding.

95. Recreation. Because floodproofing would be implemented on individual private property sites, no recreation was included in this plan.

96. Housing. This plan would do nothing to upgrade substandard housing south of the river.

97. Diversifying Vegetation. This plan would do nothing to diversify vegetation in the river.

98. EVALUATION CRITERIA. Following is a discussion on how the floodproofing plan meets Principles and Standards evaluation criteria.

99. Acceptability. All indications show that floodproofing is not acceptable to the citizens of Holbrook. Individuals do not want to be disrupted from their daily activities. They also do not desire to have their houses raised 7 feet above the ground. Non-Federal interests would be unwilling to pay $18.7 million to construct this unjustified plan.

100. The raised location of commercial and tourist related structures could have significant unacceptable effects on business activity. Local interests are not willing to undertake a major effort in coordinating this plan with each individual in the flood plain.

101. Completeness. Damages to lawns, automobile and storage yards and business and emergency losses would continue to occur. Plan is limited to remaining life of structures protected (40 years).

102. Effectiveness and Efficiency. This plan would be effective in reducing physical flood damages and providing employment opportunities in Holbrook. Lawn, automobile, emergency, and business damages would continue to occur, as would damages to property on the south side of the city. This is not an efficient plan as it would only provide 85 cents in benefits for every dollar invested (B-C ratio = .85 to 1).

103. Certainty. Should a floodproofing plan be implemented, it is probable that it would achieve its outputs. However, coordination between individual property owners may be a significant problem. It is unlikely that a majority of the property owners in the flood plain would be willing to cooperate in implementing this plan. As no attempt was made to study each building individually, there are probably cases where physical conditions such as integrity of structure or location of access would not permit raising.

104. Geographic Scope. Except for Federal or state contributions, project effects would be limited to the study area.

105. Reversibility. Construction of this plan would commit resources. Reversing the effects of this plan would require additional investment.

106. Stability. This plan would allow for future use of the flood plain and continued development of the mesa to the north and plains to the south of the flood plain. After the 40-year remaining life of the structure many may choose to move out of the flood plain. This alternative may not accommodate long-term urban use in the currently urbanized area.

Implementation Responsibilities

107. Because this plan is not economically justified, the non-Federal interests would have full responsibility for implementing this plan (first cost = $18,650,000).

SYSTEM OF ACCOUNTS

108. A comparison of the national economic development effects of the detailed plans as well as the cost apportionment is shown in Table B-3. Table B-4 summarizes the effects of the detailed plans and presents their response to the planning objectives and plan evaluation criteria.

NATIONAL ECONOMIC DEVELOPMENT PLAN

109. The National Economic Development (NED) Plan is based on the maximization of net flood control benefits (the difference between project benefits and project costs). The single-levee plan is therefore designated the NED plan, as can be seen in the comparison of net benefits shown in Table B-1. The double-levee plan is a very close second.

ENVIRONMENTAL QUALITY PLAN

110. The single-levee plan is designated the environmental quality (EQ) plan because it not only includes a diversification of vegetation by clearing salt cedar and planting grasses, cottonwoods and willows (as does the double-levee plan), but has the unique element of evacuating 70 acres on the south side and allowing it to revert to natural uses.

SELECTION OF A PLAN FOR IMPLEMENTATION

111. Selection of a plan was based on economic efficiency, contributions to environmental quality, social and regional effects, and local acceptance. Table B-4 provides a comparison of the economic, environmental, social, and regional effects of detailed plans. In accordance with current administrative policy for local protection projects, recreation benefits and costs are not included for project formulation. The following paragraphs apply to flood control only.

Economic Impact

112. Comparing the economics for the plans on Table B-3 shows that the single-levee and double-levee plans are clearly superior to the floodproofing plan. Both levee plans reduce flood damages and increase employment opportunities (they also provide recreational opportunities) and therefore address those planning objectives. Net flood control benefits for the levee plans are within 3 percent of each other ($901,000 for the single-levee plan; $880,000 for the double-levee plan). The single-levee plan is the superior performer, however, and was therefore designated the national economic development plan.

Table B-3. Economics of alternative plans.
(Cost Sharing based on President's water policy)
(September 1979 prices - 7-1/8 percent)

	Alternative 1 Single-Levee Plan	Alternative 2 Double-Levee Plan	Alternative 3* Floodproofing Plan	No Action** Plan (Base Condition)
Degree of Protection	SPF	SPF	SPF	8 yr.
Economically Justified	Yes	Yes	No	N/A
First Cost				
Flood Control				
Federal	$7,296,000	$7,163,000	$ 0	
Non-Federal	2,432,000	2,388,000	18,650,000	N/A
Subtotal, Flood Control	$9,728,000	$9,551,000	$18,650,000	
Recreation				
Federal	$ 37,000	$ 37,000		
Non-Federal	46,000	46,000	N/A	N/A
Sub-total, Recreation	$ 83,000	$ 83,000		
Total First Costs				
Federal	$7,333,000	$7,200,000	$ 0	
Non-Federal	2,478,000	2,434,000	18,650,000	N/A
Total	$9,811,000	$9,634,000	$18,650,000	
Annual Charges				
Flood Control***				
Federal	$ 520,000	$ 511,000	$ 0	
Non-Federal	177,000	208,000	1,419,000	N/A
Sub-total, Flood Control	$ 697,000	$ 719,000	$ 1,419,000	

Table B-3 (Cont.)

	Alternative 1 Single-Levee Plan	Alternative 2 Dougle-Levee Plan	Alternative 3* Flood Proofing Plan	No Action Plan (Base Condition)
Recreation				
Federal	$ 3,000	$ 3,000	N/A	N/A
Non-Federal	13,000	13,000		
Sub-total, Recreation	$ 16,000	$ 16,000		
Total Annual Charges* **				
Federal	$ 523,000	$ 514,000	$ 0	N/A
Non-Federal	190,000	221,000	1,419,000	
Total	$ 713,000	$ 735,000	$ 1,419,000	
Annual Benefits				
Flood Control	$1,598,000	$1,599,000	$1,208,000	N/A
Recreation	25,000	25,000	N/A	
Total	$1,623,000	$1,624,000	$1,208,000	
Benefit To Cost Ratio				
Flood Control***	2.3	2.2	.85	N/A
Recreation	1.6	1.6	N/A	
Total Project***	2.3	2.2	.85	
Net Benefits* **				
Flood Control	$ 901,000	$ 880,000	$ -211,000	N/A
Recreation	9,000	9,000	N/A	
Total Project***	$ 910,000	$ 889,000	$ -211,000	

* Cost sharing for non-structural plan shown for comparison purposes only. Federal Government would not participate in an unjustified plan.

** No action plan is included as a base condition for comparison of alternatives.

*** Costs for supplemental housing payments (first costs are $570,000 for 37 substandard structures for single-levee plan and $165,000 for 9 substandard structures for double-levee plan) are not included in annual charges or in the benefit-cost ratio in accordance with existing Corps' regulations (ER 1165-2-117).

Table B-4. System of accounts

ITEM	No Further Action*	PLAN Single-Levee	Double-Levee	Floodproofing
A. Impact Assessment				
1. National economic development (is project economically justified; B/C)	N.A.	Yes; B/C = 2.3	Yes; B/C = 2.2	No; B/C = 0.85
2. Environmental effects				
a. Man-made resources	N.A.	Negligible	Negligible	Negligible
b. Natural resource--wildlife habitat	N.A.	**Diversified river habitat; evacuation of 70 acres in flood plain.	**Diversified river habitat.	Negligible
c. Air pollution	N.A.	Short term in semi-populated areas during construction.	Short form in semi-populated areas during construction.	Short term in populated areas during construction.
d. Water pollution	N.A.	Negligible	Negligible	Negligible
e. Physical erosion/ sedimentation	N.A.	Reduce sedimentation by confining low flows in low-flow channel.	Reduce sedimentation by confining low flows in a low-flow channel.	Negligible--continued maintenance of local low-flow channel as in base condition.
3. Social effects				
a. Noise	N.A.	Noise in semi-populated areas during construction.	Noise-in semi populated areas during construction.	Noise in populated areas during construction.
b. Population	N.A.	Displaces about 57 families on south side of river.	Displaces about 9 families on south side of river.	Short-term displacement of 580 families during construction; permanently displaces 26 mobile homes.

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Table B-4. Continued.

ITEM	No Further Action[a]	PLAN: Single-Levee	Double-Levee	Floodproofing
c. Aesthetic values	N.A.	Levee embankments in semi-populated areas--reduction of thick river habitat; increase in larger trees in river.	Levee embankment in populated area--reduction of thick river habitat; increase in larger trees in river.	Walls and elevated structures in populated areas.
d. Residences damaged by S.P.F. on Little Colorado River	658	0	0	57 on south side of river; lawn and automobile damage to 580 on north side.
e. Businesses accepting damage from S.P.F on Little Colorado River	161	0	0	Physical damage to storage yards, parking lots, and other ground level equipment; continued business losses.
f. Business relocated	N.A.	9	2	161 business affected during construction.
g. Transportation	N.A.	Reduced flood threat to U.S. 66, and local streets --Route 77 bridge continued to be damaged.	Reduced flood threat to U.S. and local streets --minor increase in flood damage to state Route 77 bridge.	Negligible.
h. Archeologic remains/ historic structures	N.A.	Negligible	Negligible	Negligible
i. Community cohesion	N.A.	Destroy south side community.	Disrupt south side community --provide remainder of community with flood protection.	Disruptive to community during construction.

Table B-4. Continued.

ITEM	No Further Action*	PLAN Single-Levee	Double-Levee	Floodproofing
j. Housing	N.A.	Opportunity to upgrade 37 houses on south side thorugh relocation and supplemental housing payments.	Opportunity to upgrade 9 houses on south side t.rough relocation and supplemental payments.	Short-term housing needs during construction.
k. Damage from tributaries	$39,000	$46,000	$46,000	$4,000
4. Regional economic effects				
a. Employment	N.A.	12 laborers employed during peak construction total of 220 person-weeks.	16 laborers employed during peak construction total of 256 person-weeks.	Almost 3,000 person-weeks of unskilled laborer employed.
b. Regional growth	N.A.	Negligible	Negligible	Negligible
c. Removal of tax base	N.A.	Short-term removal will be mitigated by reduction of flood threat--long-term increase.	Short-term removal will be mitigated by reduction of flood threat--long-term increase.	Long-term increase in tax base due to reduction of flood threat.
B. Does Plan Achieve Planning Objectives/ Gross Annual Benefits				
1. Flood damage reduction	N.A.	Yes/$1,574,000	Yes/$1,588,000	Yes/$1,159,000
2. Recreation	N.A.	Yes/$25,000	Yes/$25,000	No
3. Improved housing	N.A.	Yes/$570,000	Yes/$165,000	No
4. Diversified vegetation	N.A.	Yes	Yes	No

Table B-4. Continued.

ITEM	No Further Action*	PLAN Single-Levee	Double-Levee	Floodproofing
C. Plan Evaluation Criteria				
1. Acceptability	N.A.	Opposition from City and residents on south side.	No strong opposition.	Strong opposition from City and residents.
2. Completeness	N.A.	Action is complete.	Action is complete	Continued flooding of lawns, equipment yards, automobiles. Continued safety and health hazard.
3. Effectiveness/ efficiency	N.A.	Effective/NED plan Net benefits = $910,000	Effective/ Net benefits = $889,000	Effective but to lesser degree than levees/ Net benefits = $-211,000
4. Continuity	Likely	Likely	Likely	Possibly
5. Geographic scope	Study area	Study area	Study area	Study area
6. Reversibility	Considerable	Negligible	Negligible	Negligible
7. Stability	Low	Considerable	Considerable	Considerable, but less than levees.

*Without project condition
**Cottonwoods and willows, along with the alkali sacaton and saltgrass planted in the cleared strip, will provide more diverse habitat value than the salt cedar to be removed for the cleared strip. However, revegetation measures will not result in a net beneficial impact because of the O&M clearing requirements.

113. The floodproofing plan was not found to be economically justified. Annual costs for this plan would exceed average annual benefits by $211,000.

Environmental Effects

114. Both the single- and double-levee plans are considered to add to diversification of habitat in the Little Colorado Riverbed, and therefore address that planning objective. The single-levee plan was found to be superior in the environmental quality account, because it calls for evacuation of 70 acres of flood plain land and would permit that land to revert to its natural flood plain uses. The single-levee plan was therefore designated the environmental quality plan.

115. The floodproofing plan has negligible environmental effects except those that may result from landscaping of the individual structures.

Regional Effects

116. The significant regional effects of the plans include increased employment opportunities and local cost sharing.

117. All plans provide increased employment opportunities, but the floodproofing plan is clearly superior in this aspect because of the labor intensity of plan construction.

118. Non-Federal first costs for the levee plans are very close ($2,478,000 for the single-levee plan and $2,434,000 for the double-levee plan). The floodproofing plan would require a non-Federal expenditure of about $18.7 million because it is not economically justified (see table B-3).

Social Effects

119. The most significant social impact of the levee plans would be the reduction of the flood hazard on both sides of the river and the necessary relocations of people. Although the single-levee plan requires the relocation of 57 families and would possibly meet the planning objective of upgrading housing through supplemental housing payments, availability of substitute housing and adequacy of supplemental housing payments to cover real costs could pose a significant problem in implementing this plan. Even if housing were available, this plan would probably contribute to the current housing shortage and inflate housing costs. Also, this plan would virtually destroy the community cohesiveness and character on the south side of the river. The inability of some of the people to be relocated to assume even a modest increase in housing cost, whether for rent, mortgage or taxes, makes the implementability of the south side evacuation questionable.

120. The double-levee plan, though modest in its goals for upgrading housing (9 families would be relocated), would probably attain this objective without the problems associated with a large scale evacuation. The double-levee plan would protect the south-side community and, by eliminating the constant threat of flooding, encourage residents to improve housing at their own pace.

121. Although the floodproofing plan would not relocate any permanent structures (approximately 26 mobile homes would be moved), this plan would disrupt 580 families during construction.

122. Both the levee plans and the floodproofing plan would reduce the economic cost of flood damages and/or flood insurance premiums. A risk to health, safety, and loss of life would remain with the floodproofing plan.

Acceptance

123. The City of Holbrook supports the double-levee plan (see City Council Resolution, included in Appendix A, "Public Views and Responses"). The number of relocations required for the single-levee plan and concommittant problems dictated their position. The city foresees problems in providing replacement housing and in actually accomplishing the relocations. The city is opposed to the floodproofing plan because of its high local cost and other related problems of required coordination between property owners and the physical condition and structural integrity of the buildings involving much of the city of Holbrook.

124. South-side residents have voiced an opposition to the single-levee plan. They generally prever preservation of their existing community through construction of the double-levee plan.

Summary

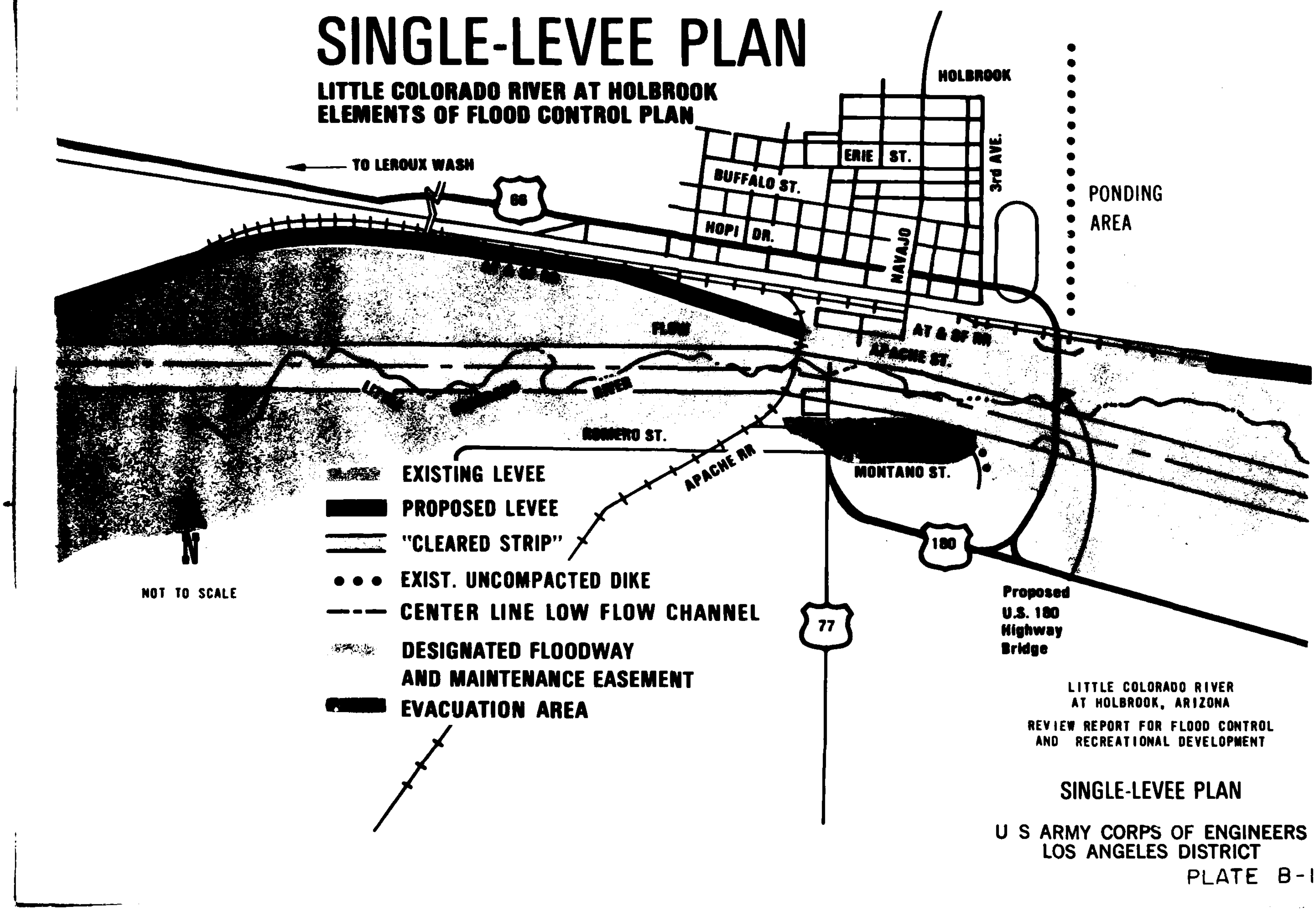
125. Comparison of the three detailed plans showed the levee plans to be superior to the floodproofing plan. Because the floodproofing plan was found to have a benefit-cost ratio of less than one, and does not have any redeeming environmental effects, it was eliminated from further consideration.

126. The single-levee plan was found to be somewhat superior both economically and environmentally to the double-levee plan. However, because of the uncertainty involved in the relocations of south-side residents for the single-levee plan, and because the south side residents have expressed preference for the double-levee plan, the double-levee plan was found to be superior in its social effects.

127. As expressed in a resolution passed by the Holbrook City Council (see Appendix A, "Public Views and Responses"), local interests support the double-levee plan. A major factor in this choice was the uncertainty of providing adequate replacement housing for the south-side

residents should the single-levee plan be chosen. The locals are especially reluctant to bear the responsibility of actually accomplishing the relocations.

128. In summary, the single-levee and double-levee plans are very close in their economic and environmental contributions. Local acceptance and uncertainties posed by the relocations required as part of the single-levee plan were considered more significant factors in choosing a plan. The double-levee plan was therefore chosen for implementation.


SINGLE-LEVEE PLAN
LITTLE COLORADO RIVER AT HOLBROOK
ELEMENTS OF FLOOD CONTROL PLAN
TO LEROUX WASH
66
HOLBROOK
ERIE ST.
BUFFALO ST.
HOPI DR.
NAVAJO
3rd AVE.
PONDING
AREA
FLOW
AT & SF RR
APACHE ST.
RIVER
ROMERO ST.
APACHE RR
MONTANO ST.
180
77
Proposed
U.S. 180
Highway
Bridge
N
NOT TO SCALE
EXISTING LEVEE
PROPOSED LEVEE
"CLEARED STRIP"
EXIST. UNCOMPACTED DIKE
CENTER LINE LOW FLOW CHANNEL
DESIGNATED FLOODWAY
AND MAINTENANCE EASEMENT
EVACUATION AREA
LITTLE COLORADO RIVER
AT HOLBROOK, ARIZONA
REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT
SINGLE-LEVEE PLAN
U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT
PLATE B-1

LEGEND

SPF
100 YEAR FLOOD
50 YEAR FLOOD
LEVEE

N

SCALE 800 0 800 FEET

LITTLE COLORADO RIVER
AT HOLBROOK, ARIZONA

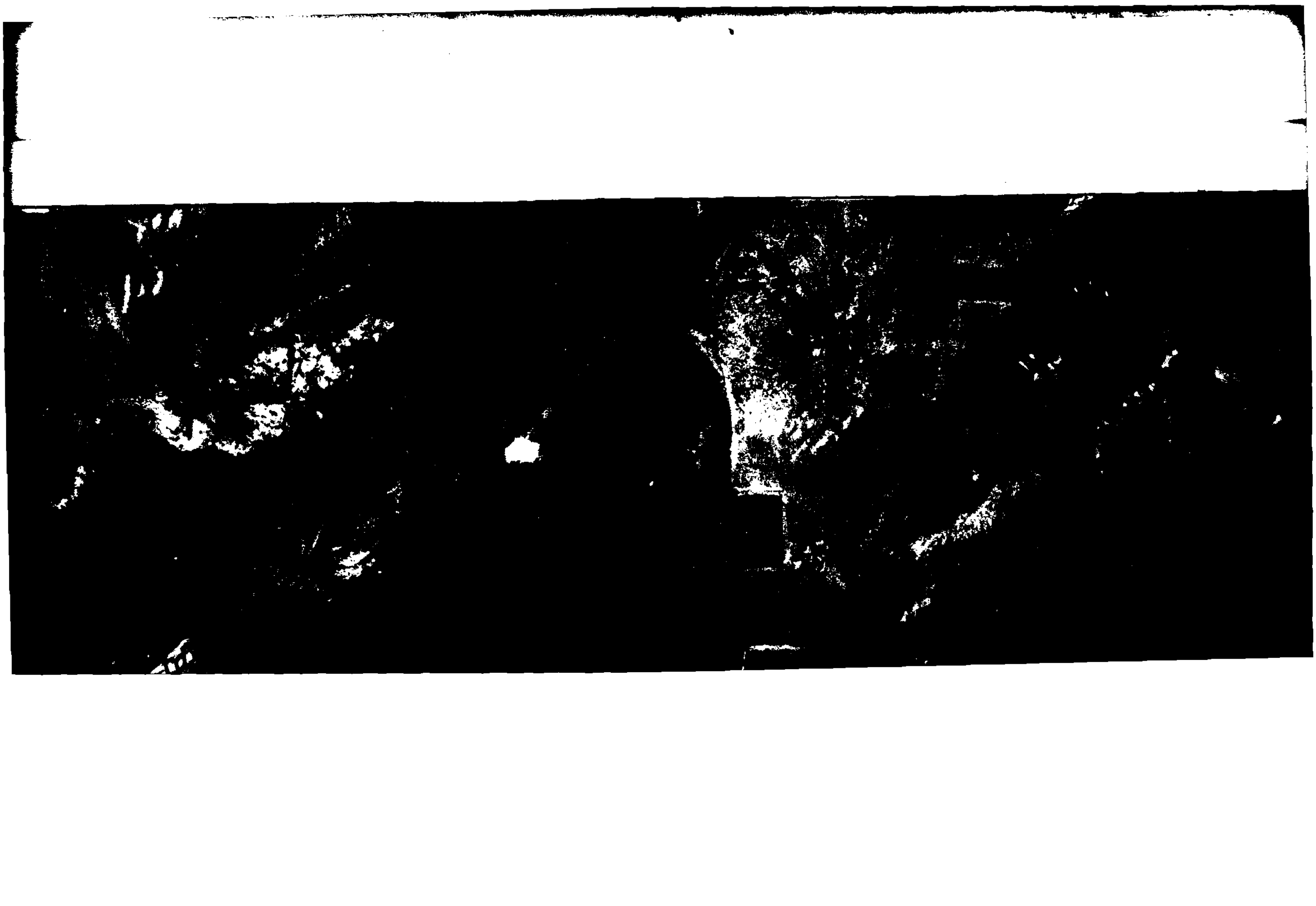
REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

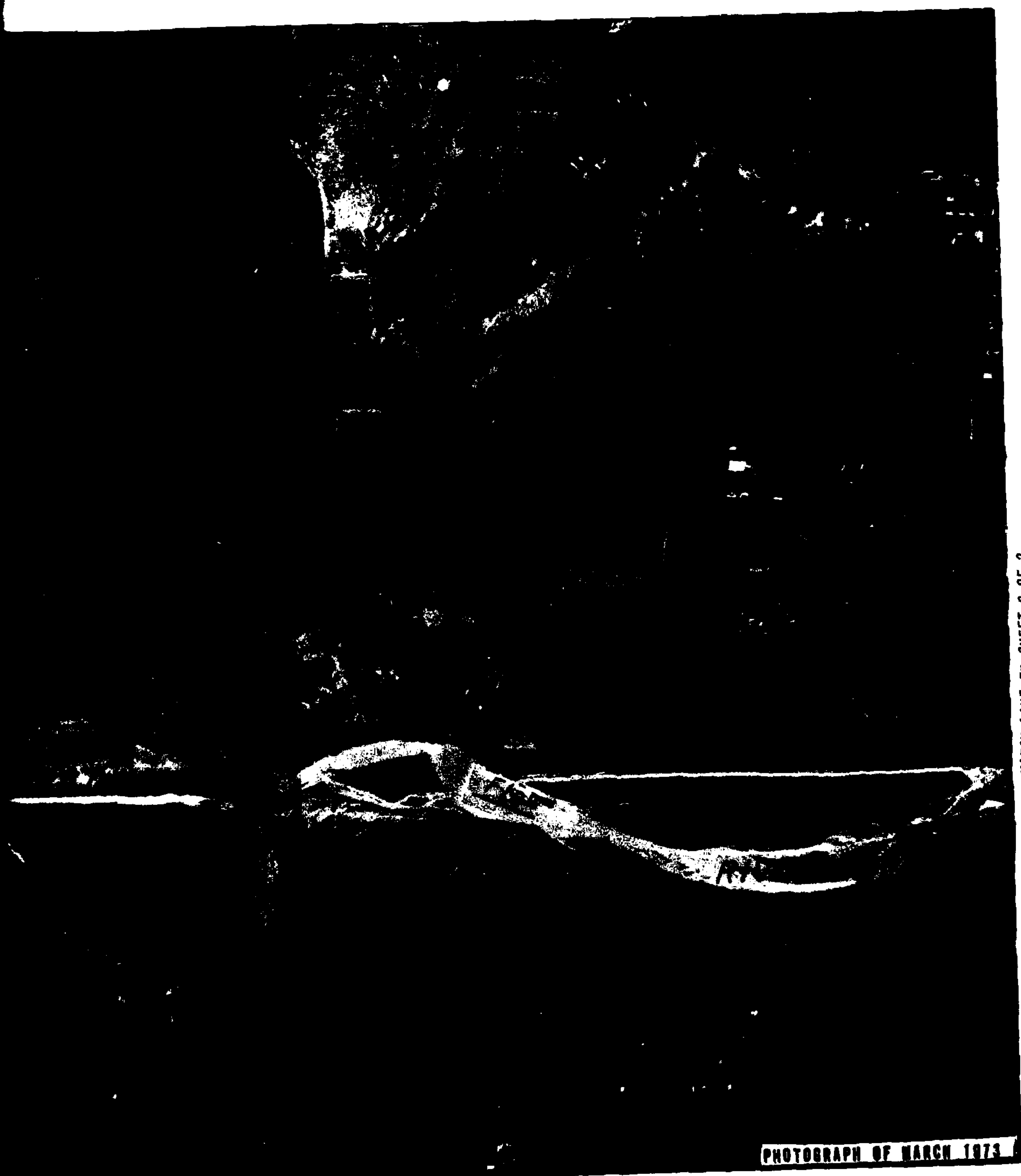
**AREA SUBJECT TO FLOODING
BY THE LITTLE COLORADO RIVER**

**SINGLE LEVEE PLAN
POST PROJECT CONDITIONS**

**U S ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS**

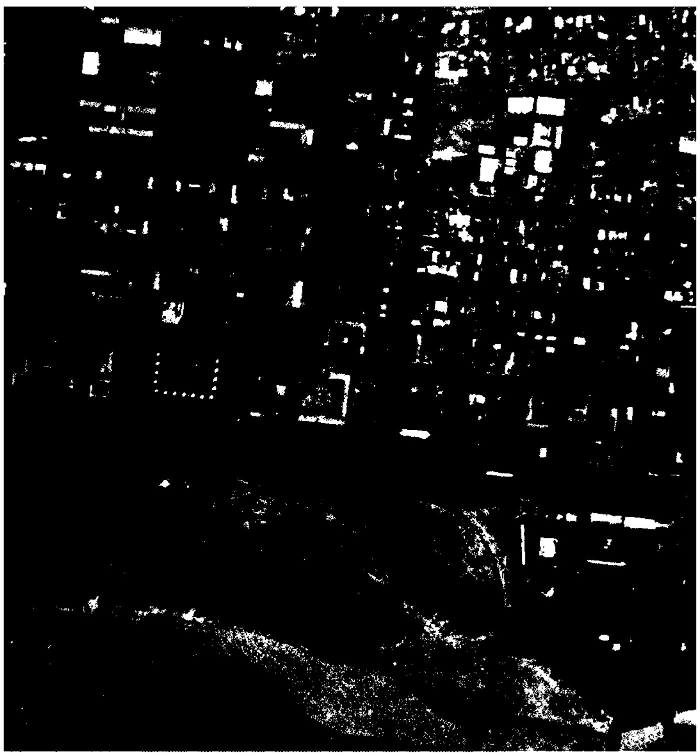
SHEET 1 OF 2 PLATE B-2

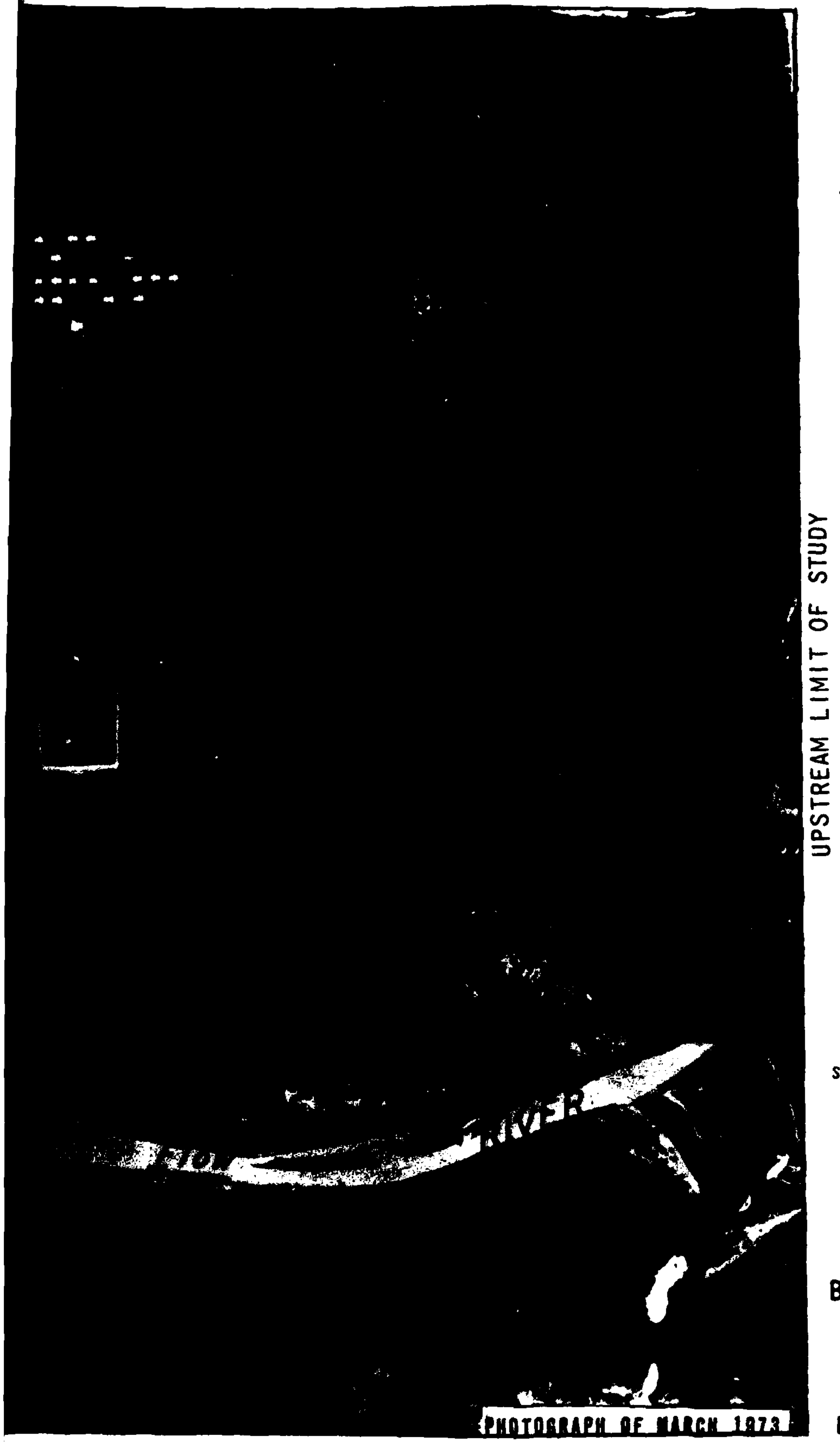




MATCH LINE TO SHEET 2 OF 2

2 1 3





LEGEND

SPF

100 YEAR FLOOD

50 YEAR FLOOD

LEVEE

N

SCALE 800 0 800 FEET

LITTLE COLORADO RIVER
AT HOLBROOK, ARIZONA

REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

AREA SUBJECT TO FLOODING
BY THE LITTLE COLORADO RIVER

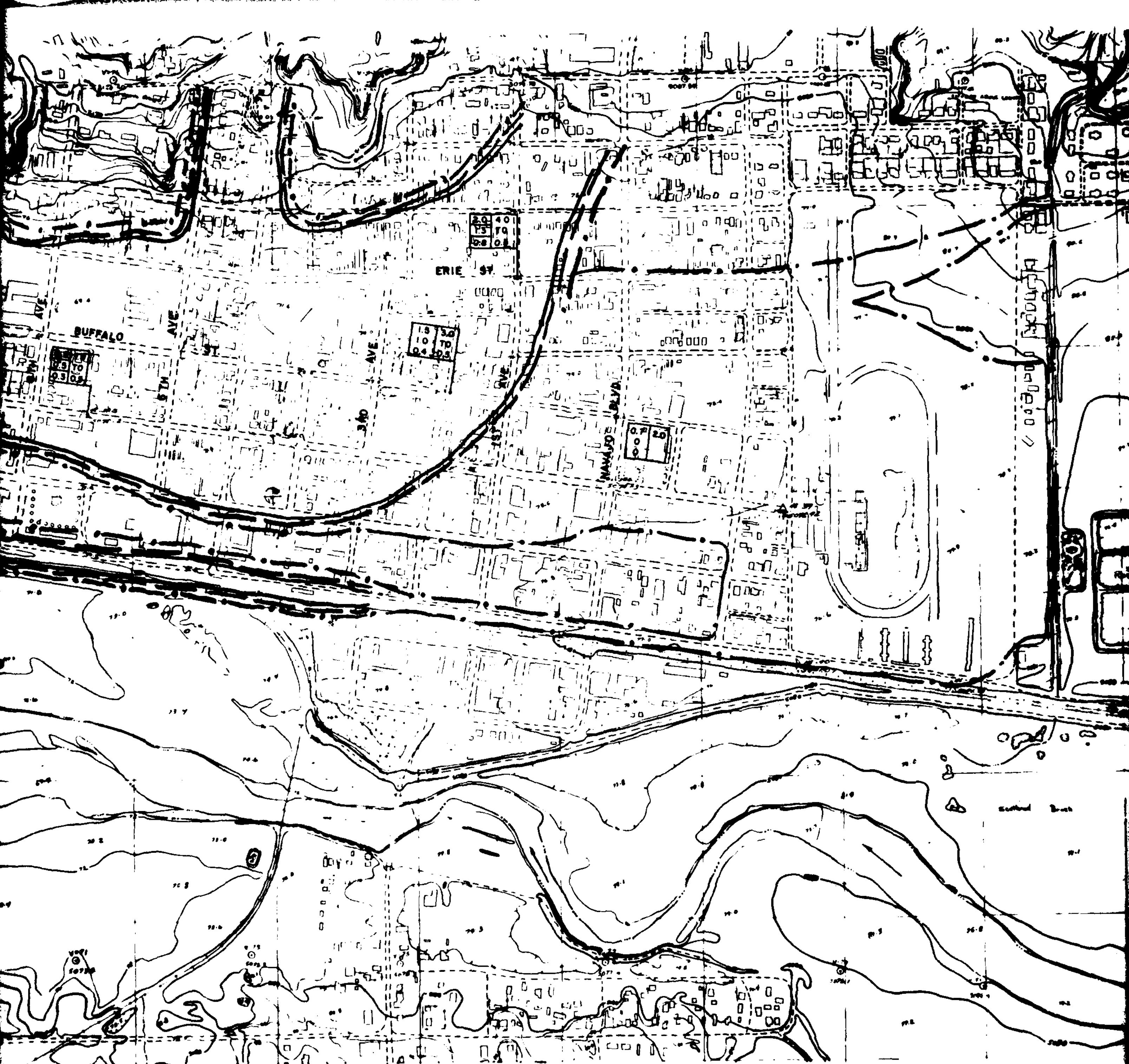
SINGLE LEVEE PLAN
POST PROJECT CONDITIONS

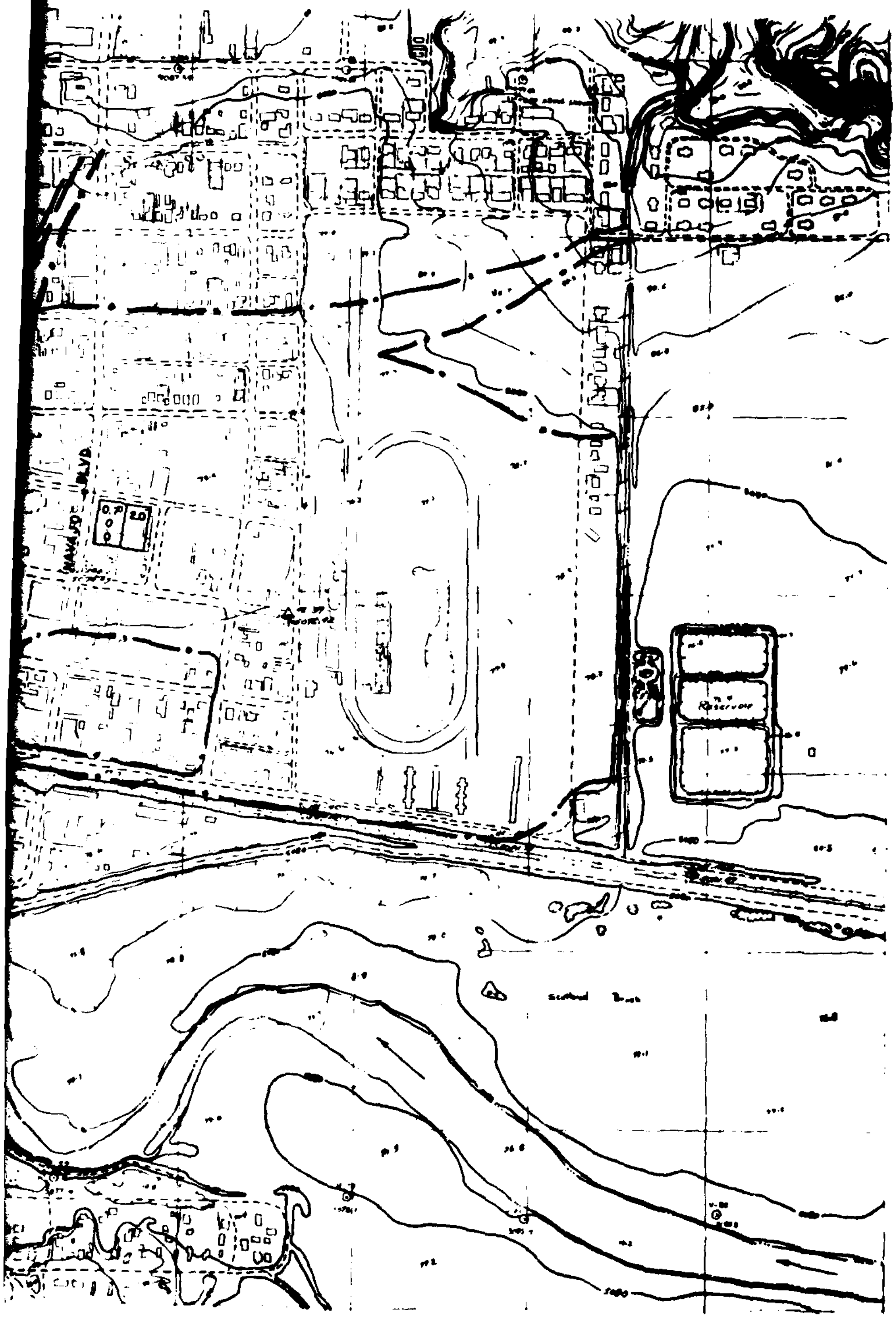
U S ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

SHEET 2 OF 2 PLATE B-2

2 1 3

13TH AVE
12
BUFFALO
AVE


BUFFALO
ST.
ERIE ST.
5TH AVE
3RD AVE
1ST AVE
NAVAJO BLVD.



LEGEND

———	STANDARD PROJECT FLOOD
— —	100 YEAR FLOOD
— · —	50 YEAR FLOOD

	DEPTH IN FEET	VELOCITY IN FEET PER SECOND
SPF	3.0	2.0
100 YR	2.0	to
50 YR	1.0	1.0

N

SCALE IN FEET
500 0 500

LITTLE COLORADO RIVER
AT HOLBROOK, ARIZONA

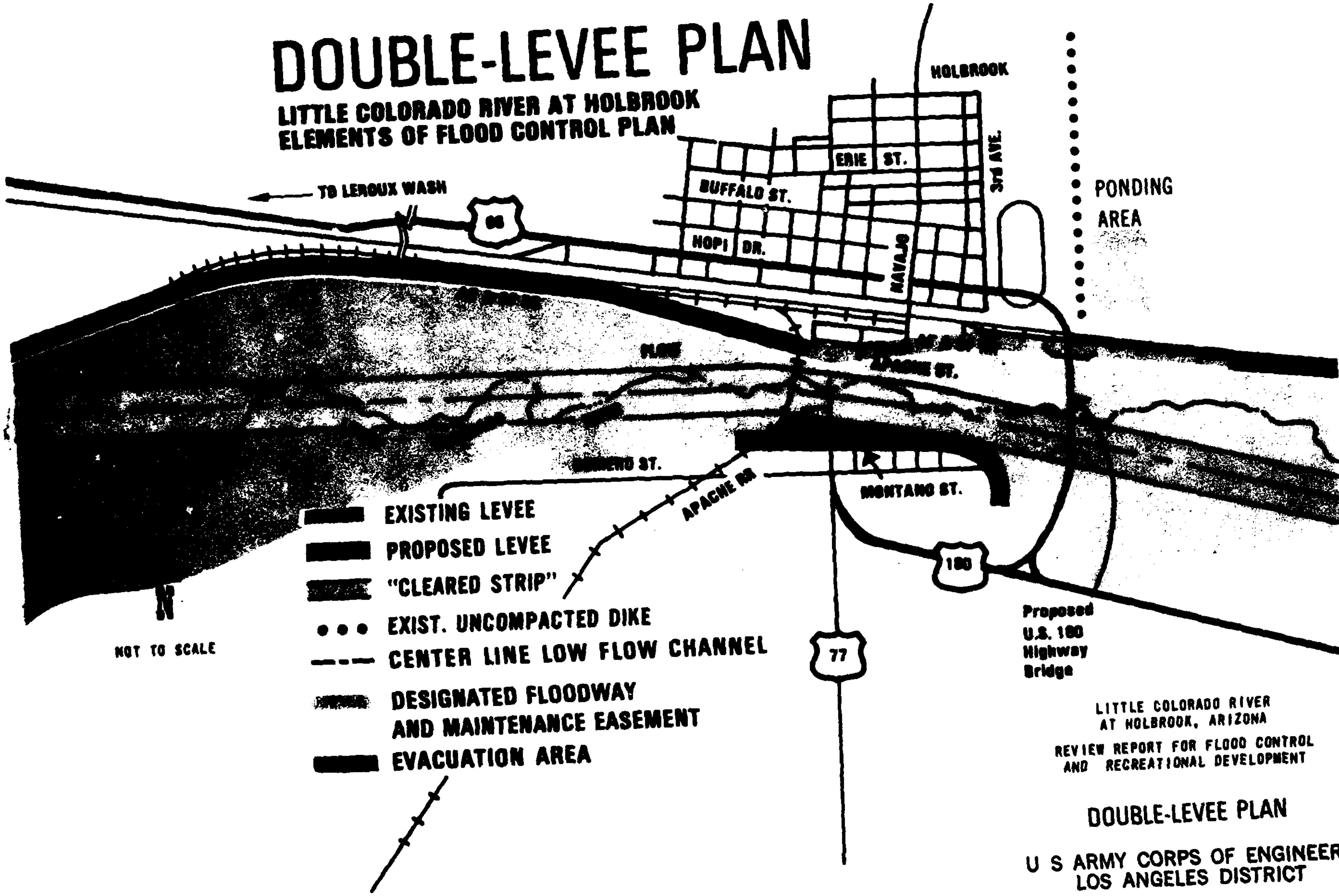
REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

AREA SUBJECT TO FLOODING

BY TRIBUTARIES OF THE
LITTLE COLORADO RIVER
POST-PROJECT CONDITIONS

U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE B-3



LITTLE COLORADO RIVER
AT HOLBROOK, ARIZONA

REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

DOUBLE-LEVEE PLAN

U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE B-4

LEGEND

SPF
100 YEAR FLOOD
50 YEAR FLOOD
LEVEE

N

SCALE 800 0 800 FEET

LITTLE COLORADO RIVER
AT HOLBROOK, ARIZONA

REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

AREA SUBJECT TO FLOODING BY THE LITTLE COLORADO RIVER
DOUBLE LEVEE PLAN
POST PROJECT CONDITIONS

U S ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

SHEET 1 OF 2 PLATE B-5

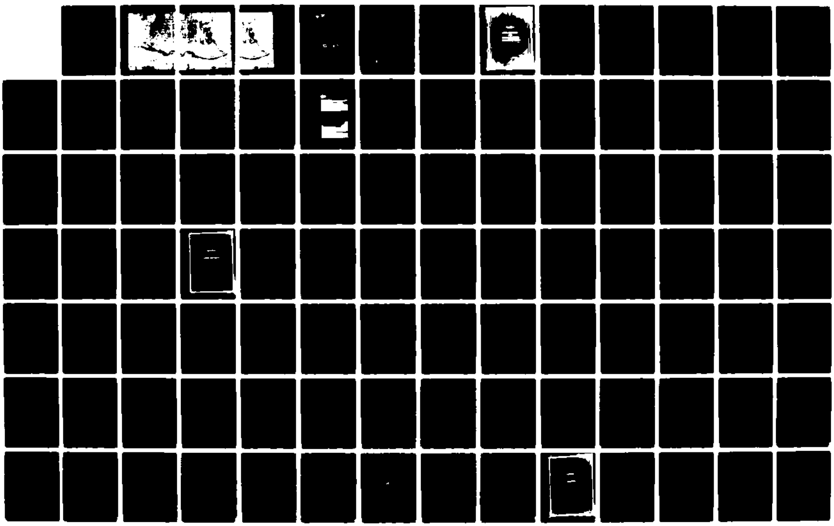
MATCH LINE TO SHEET 2 OF 2

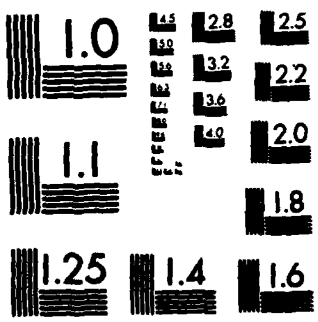
2 1 3

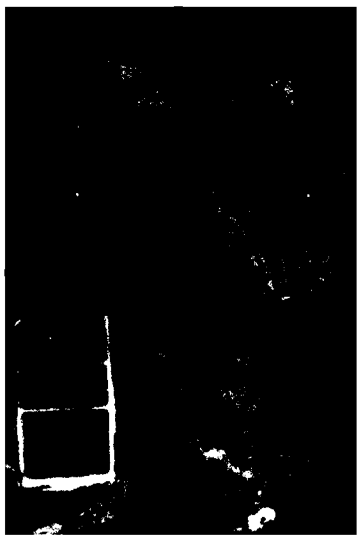
AD-A136 661 REVIEW REPORT FOR FLOOD CONTROL AND RECREATIONAL DEVELOPMENT LITTLE COLOR..(U) ARMY ENGINEER DISTRICT LOS ANGELES CA SEP 80

2/4

UNCLASSIFIED F/G 13/2 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0



LEGEND

- SPF
- 100 YEAR FLOOD
- 50 YEAR FLOOD
- LEVEE

N

SCALE 800 0 800 FEET

LITTLE COLORADO RIVER
AT HOLBROOK, ARIZONA

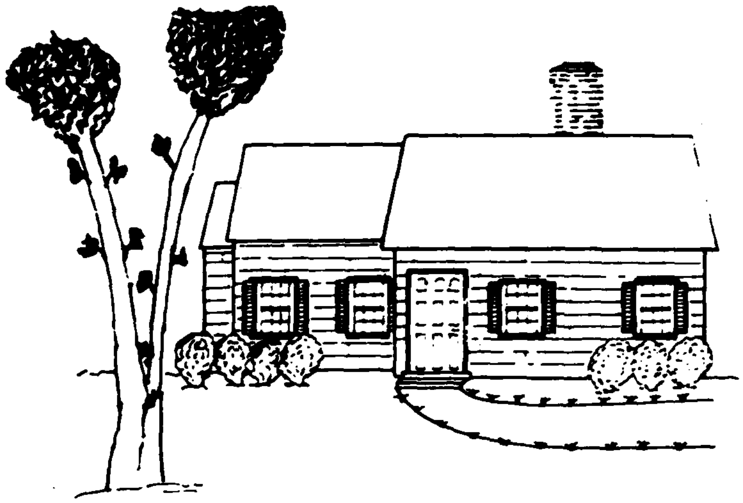
REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

AREA SUBJECT TO FLOODING
BY THE LITTLE COLORADO RIVER

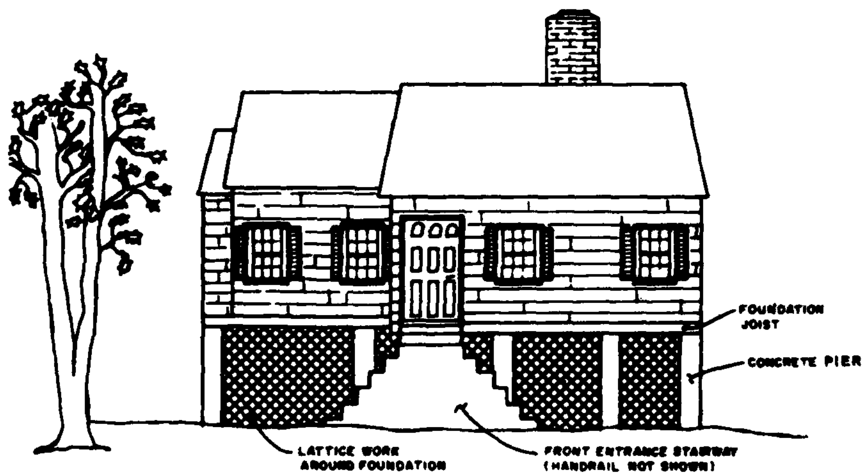
DOUBLE LEVEE PLAN
POST PROJECT CONDITIONS

U S ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

SHEET 2 OF 2 PLATE B-5



RESIDENCE BEFORE RAISING



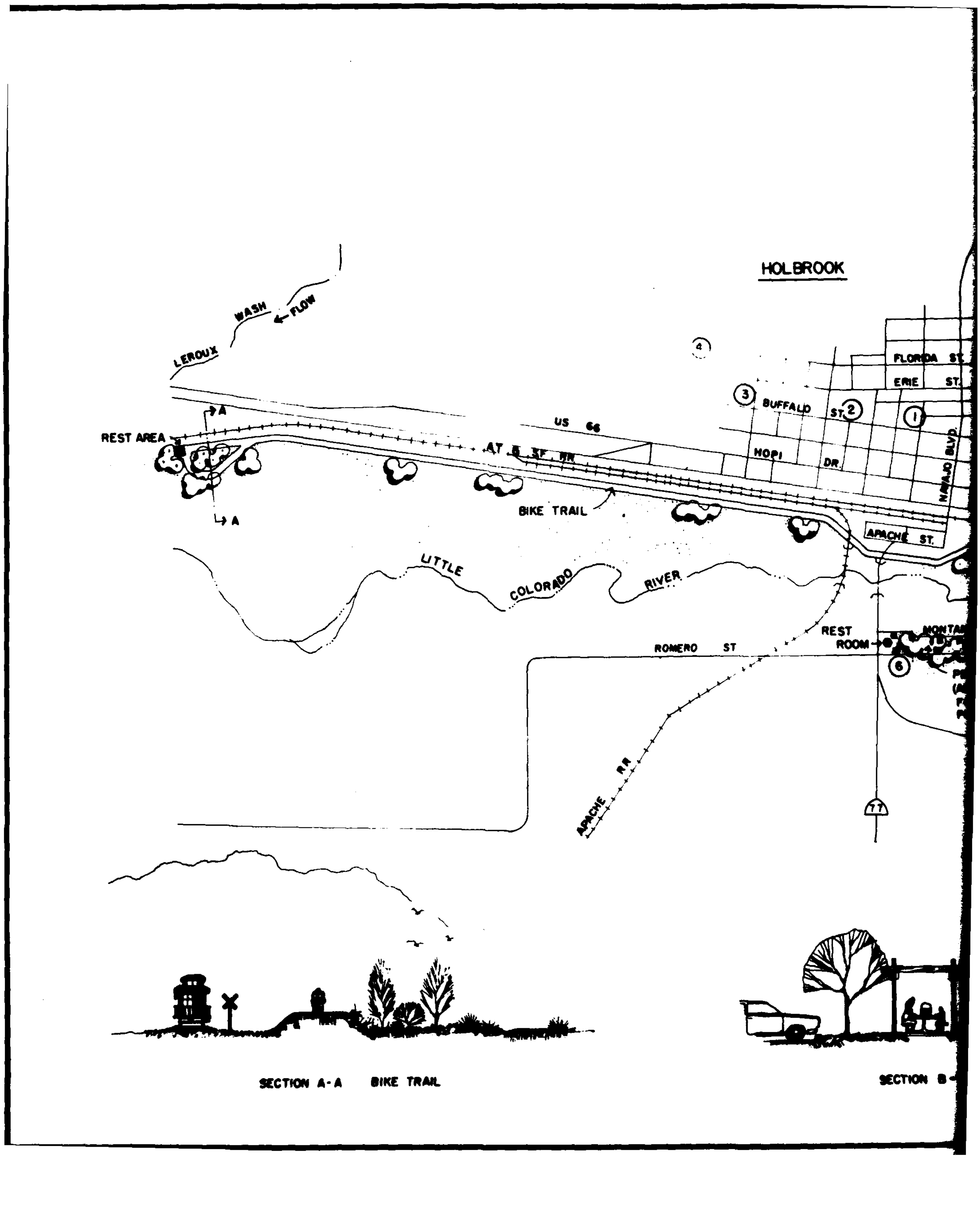
RESIDENCE AFTER RAISING

LITTLE COLORADO RIVER
AT HOLBROOK, ARIZONA

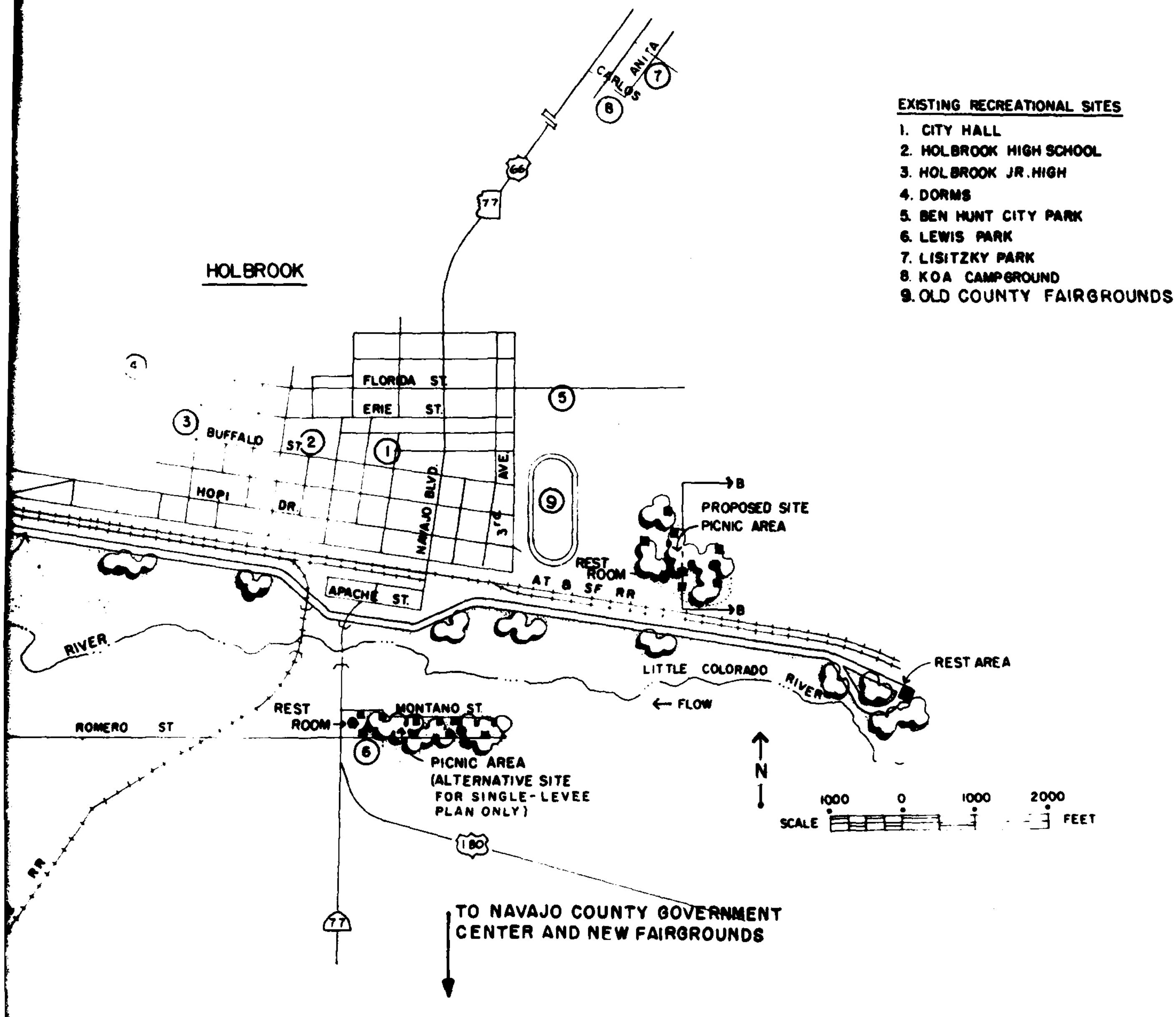
REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

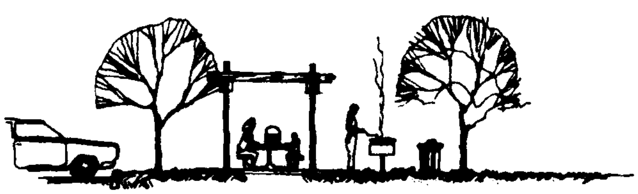
FLOODPROOFING PLAN

U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



HOLBROOK
LEROUX WASH
FLOW
FLORIDA ST.
ERIE ST.
BUFFALO ST.
HOPI DR.
NAVAJO BLVD.
APACHE ST.
US 66
AT & SF. RR
REST AREA
A
BIKE TRAIL
LITTLE COLORADO RIVER
ROMERO ST
REST ROOM
APACHE R.R.
77
1
2
3
4
6
SECTION A-A BIKE TRAIL
SECTION B





SECTION B-B PICNIC SITE (TYP.)

LITTLE COLORADO RIVER
AT HOLBROOK, ARIZONA

REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

RECREATION PLAN

U S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Section C

SOCIAL CONDITIONS AND CULTURAL RESOURCES

CONTENTS

SOCIAL CONDITIONS IN
HOLBROOK

GENERAL

1. Social problems of Holbrook and Navajo County that can impact upon or be impacted upon by implementation of a flood control project include unemployment, shortage of housing, separation of the south-side community, substandard housing and poverty of the south-side residents, and the flood threat on both sides of the river.

UNEMPLOYMENT

2. Despite the influence of the construction of the Cholla Powerplant and Interstate 40, unemployment in Holbrook and Navajo County has remained high. The latest available statistics showed the unemployment rate to be 11.7 percent in Navajo County (October 1979) and 9.0 percent in Holbrook (April 1979).

HOUSING

3. The existing housing stock in Holbrook has been overtaxed by the influx of construction workers. However, there has been a reluctance of investors to finance extensive new home construction because the normal economic base of Holbrook is substantially lower than the present temporary condition caused by powerplant and highway construction.

SOUTH-SIDE COMMUNITY

4. Most of the people living on the south side of the river are poor and black. A few Hispanics also live in the community. The main attraction to the area is inexpensive housing, most of which is substandard. The area has been subject to flooding in the past, and at present the city does not permit development except on the floodway fringe and only if the development is protected to the 100-year flood level. Despite the poor condition of the south-side community and the poverty of its residents, a fairly strong sense of community exists. The inhabitants tend to identify and be identified with their community and they have their own leaders and have established their own churches through which much of the community's social and political activity is organized. Although the people and politicians of Holbrook tend to some extent to look on the south side as a separate unit, they have not ignored the needs of the south side. After the floods of 1970 and 1971 a dike was constructed to protect south-side development. Although the dike has increased the level of protection to the south side, it would be inadequate against a large flood. A self-help housing program was also instituted through the Farmers Home Administration, and several

former south-side residents were able to build and occupy new homes through this program. Over 30 households still occupy the south side flood plain and are threatened by severe flooding.

THE FLOOD THREAT

5. The flood threat to Holbrook presents serious social problems. In addition to the potential for injury, sickness, and loss of life, thousands of people would be forced from their homes during a major flood event. Because of the present housing shortage in Holbrook, which is not likely to abate in the near future, providing emergency housing for such a large number of people would be very difficult. Community activities and normal routines would be disrupted indefinitely. People affected by flooding would have to undergo the anxieties and frustrations of dealing with unfamiliar government agencies and regulations. Use or personal funds and time would be diverted to flood recovery activities instead of being used for improving quality of life.

6. Residents of the south-side community would suffer all the flood-related social problems of their north-side neighbors plus some problems unique to the south side. Residents of the south side face a more uncertain future than those in the main part of the city. South-side property owners who are financially able to improve their properties are prevented from doing so by the flood threat. Most of the south siders are poor and many live on fixed incomes in the only housing they can afford. Should their homes be destroyed or otherwise be made or declared uninhabitable, affordable alternative housing would not be available. Existing governmental programs for dealing with such a situation are indirect, time consuming and uncertain. People living at or near subsistence level incomes would find economic recovery slower and more difficult while waiting for government assistance and from losses not covered by government assistance.

MUSEUM OF NORTHERN ARIZONA
DEPARTMENT OF ANTHROPOLOGY

AN INTENSIVE ARCHAEOLOGICAL SURVEY OF PROPOSED RECHANNELIZATION AREAS AND ASSOCIATED LEVEES NEAR HOLBROOK, NAVAJO COUNTY, ARIZONA

By

A. Stanley Granger

and

Donald E. Weaver, Jr.

Submitted by:

Alexander J. Lindsay, Jr.
Coordinator of Archaeological Research
Department of Anthropology
Museum of Northern Arizona
Flagstaff, Arizona 86001

Prepared for:

U. S. Department of the Army
Los Angeles District
Corps of Engineers
Los Angeles, California 90053
Contract No. DACW09-77-M-1486

December, 1977

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LIST OF FIGURES

MANAGEMENT SUMMARY

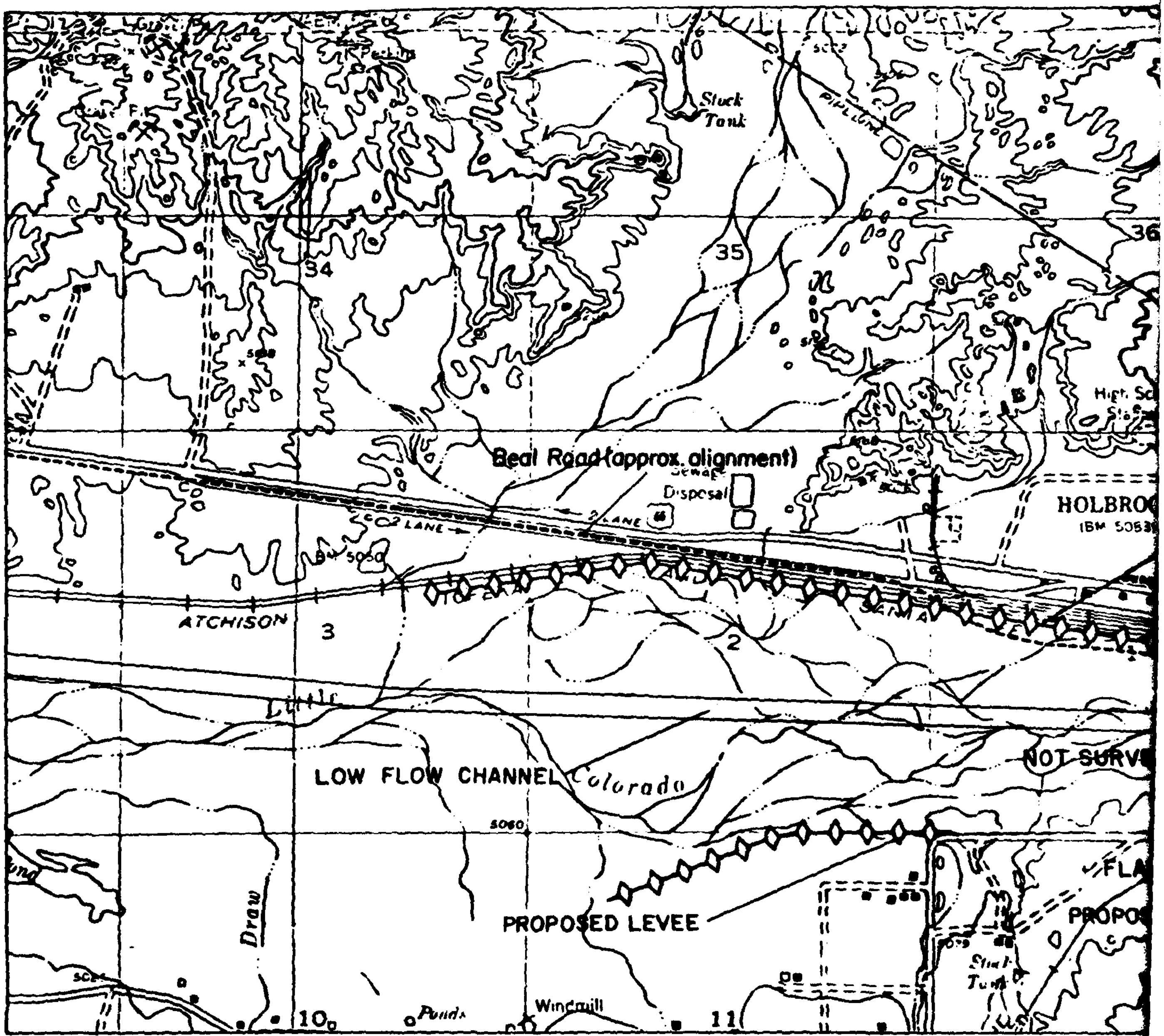
Between August 29 and September 1, 1977, the proposed areas of rechannelization of the Little Colorado River and associated levees near Holbrook, Navajo County, Arizona, were surveyed by the Museum of Northern Arizona. The proposed channelization of the river measured 7.3 miles in length and 300 feet in width. In addition, five proposed levees, ranging in length from 0.3 miles to 2.3 miles were surveyed for a total of 4.3 miles. The levee areas surveyed were 50 feet wide. No archaeological sites, prehistoric or historic, were discovered in any of the surveyed areas, and no further archaeological investigations are recommended prior to the initiation of construction activities. The lack of surficial evidence of archaeological sites is in past due to heavy alluviation, flooded conditions, heavy vegetation, and recent ground disturbance. It is recommended that ground cutting phases of proposed construction activities be periodically monitored by qualified archaeologists.

ABSTRACT: Between August 29 and September 1, 1977, the proposed rechannelization area of the Little Colorado River and associated levees near Holbrook, Navajo County, Arizona, were surveyed by the Museum of Northern Arizona. The project was conducted at the request of the U. S. Department of the Army, Los Angeles District, Corps of Engineers under contract number DACW09-77-M-1486. No archaeological sites, prehistoric or historic, were located during the survey. A description of the project, the cultural background of the project area, and details of the fieldwork conducted are presented in the following report.

INTRODUCTION

At the request of the U. S. Department of the Army Corps of Engineers approximately 12 miles of proposed rechannelization of the Little Colorado River and associated levees were surveyed by the Museum of Northern Arizona. The majority of the project area consists of the rechannelization itself, a corridor 300 feet wide running either in the present bed of the Little Colorado River or along its banks. The levee areas consist of five non-contiguous areas some distance away from the river bed but still on the floodplain of the river. The project area is located within Sections 1, 2, 3, 4 and 11 of T17N, R20E, and Sections 5, 6, 7 and 8 of T17N, R21E, extending roughly from 4 miles west of Holbrook to 2 miles east of that city (see Fig. 1). Actual survey work was carried out between August 29 and September 1, 1977, under the field supervision of A. Stanley Granger. Regular crew members were Marilyn Bender and Peggy Gaudy. Donald E. Weaver, Jr. assisted with the field work on August 31, 1977. All project areas were systematically covered on foot.

At the time the survey was carried out, the river was several weeks past the peak of its annual summer flood. Although there was still a significant flow of water in the channel, most of the river bed was covered with mud and sand in various stages of dessication (see Fig. 2). In addition, several areas of quicksand, an unstable semi-liquid mixture of sand, mud, and water, were noted in the river channel. Previous rechannelization of the Little



Stuck Tank
34
35
Beal Road (approx. alignment)
Disposal
HOLBROO
ATCHISON
3
2
Little
LOW FLOW CHANNEL
Colorado
5060
PROPOSED LEVEE
Draw
10
Ponds
Windmill
11

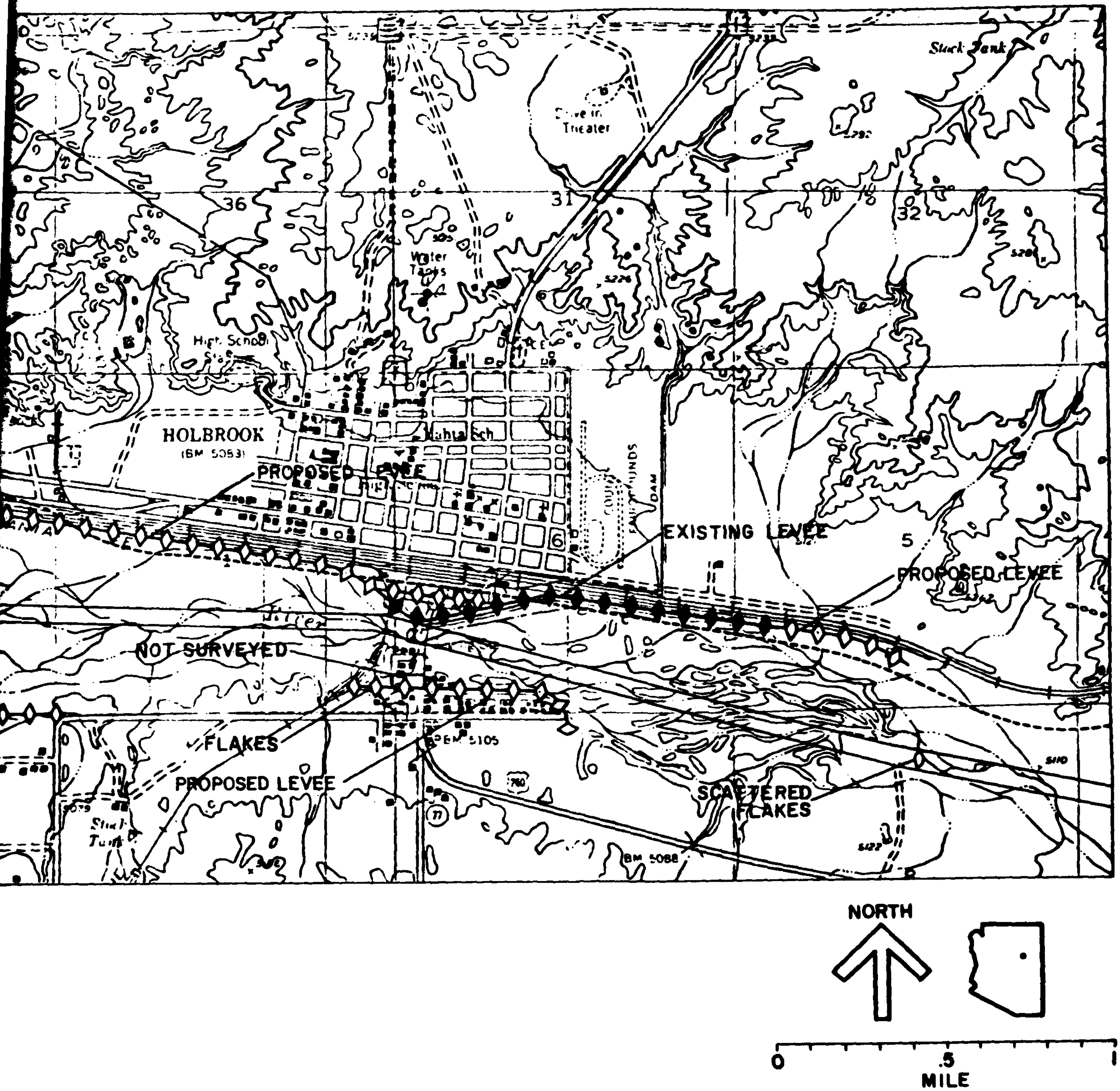


Figure 1: Map of project area, showing areas surveyed.

Figure 2. Bed of the Little Colorado River

Figure 3. Heavy Vegetation along the Banks of the Little Colorado River

Colorado by the City of Holbrook has also had major effects on the present course of the river. In many places where rechannelization has been carried out, the former course of the river is barely discernable, being several feet above the present course and almost entirely overgrown by dense riparian vegetation.

Environment of the Study Area

The Little Colorado River is one of the major drainages of the Colorado Plateau physiographic province. It, along with its tributaries, drains the major portion of northeastern Arizona. The areas surveyed lie entirely within the flood-plain of the Little Colorado River.

The banks of the Little Colorado are characterized by riparian vegetation growing in the alluvial silt deposited by the river in its periodic floods. The major constituents of this vegetation are cottonwood trees, desert willow, and tamarisk, an exotic species introduced to the southwest from Asia in the 19th century. The spread and growth of tamarisk has been so exuberant that these plants now cover large sections of the river bank and grow so thickly that foot travel in these areas is almost impossible (see Fig. 3).

Levee areas surveyed are for the most part identical in soils and vegetation to the river bank areas described above. The only major difference noted in these areas is the presence of sand dunes. The features are composed of aeolian sand and are either stabilised by various grasses

and small shrubs, or are unstable and subject to periodic shifting by wind action. Generally the proposed emplacements for the levees are identical to the river bank areas, that is, are characterized by recent water deposited silt and dense riparian vegetation.

In general, the areas surveyed may be characterized as riparian. Due to this, the ground surface present during any prehistoric occupation of the area was rarely if ever visible. This may to some degree explain the dearth of noted cultural remains.

REGIONAL CULTURE HISTORY (adapted from Haas, 1973)

Paleo-Indian

Human occupation in this region may cover a time span of 12,000 years. Clovis and Folsom projectile points, indicators of Paleo-Indian activity from 9,500 to 7,000 B.C., have been found near Winslow (Sims and Daniel 1967), as well as at other locations in the Little Colorado Valley (Agenbroad 1967). However, no such evidence has been reported specifically within the present study area.

Desert Culture

The existence of the "Tolchaco" culture was first postulated by Katharine Bartlett (1943) from lithic debris and percussion flaked tools including scrapers and hand axes found on ridges of the first terrace of the Little Colorado River. Few projectile points, or other temporally diagnostic artifacts have been found. Although dating is as yet uncertain for this material, much of it is thought to be early and in some way related to the Desert culture horizon of 4,000 to 1,000 B.C.

The term Desert culture refers to a tradition of subsistence based upon gathering and hunting. The inventory of tools characteristic of this period include one-hand size manos, basin metates, baskets, and regionally distinctive projectile points. Definite Desert culture occupation has been identified near Winslow, where surface Pinto points

have been found (Sims and Daniel 1967), on the periphery of the middle Little Colorado near Concho (Wendorf and Thomas 1951), and at other locations in the Little Colorado Valley.

In summary, little work has been done in this area in the realm of Early Man archaeology, and therefore little can be said, aside from the fact that man has occupied the central Little Colorado River Valley since very early times.

Anasazi

Archaeologists generally agree that after the Desert culture period the geographic extent of the central Little Colorado River Valley came to define a fairly homogeneous archaeological area referred to by the same name - the central or middle Little Colorado area. This archaeological and geographic area corresponds to the distribution of "pure" Little Colorado White Ware sites, dating from A.D. 1075 to 1250 (Gumerman and Skinner 1968: 185), which belong to the Anasazi culture. "Anasazi" refers to the peoples who inhabit the San Juan, Colorado, and Little Colorado drainages prior to Spanish arrival in the southwest - Pueblo Indians and their predecessors, the Basketmakers. The archaeological distinctiveness of the region is probably related to its positioning between two major culture areas, the Sinagua and Mogollon (see Fig. 4) and is reinforced by its arid, basin environment. What results from the interaction of these two factors seems to be a mixing of cultural elements along with a regional environmental adaptation (Gumerman and Skinner 1968: 185).

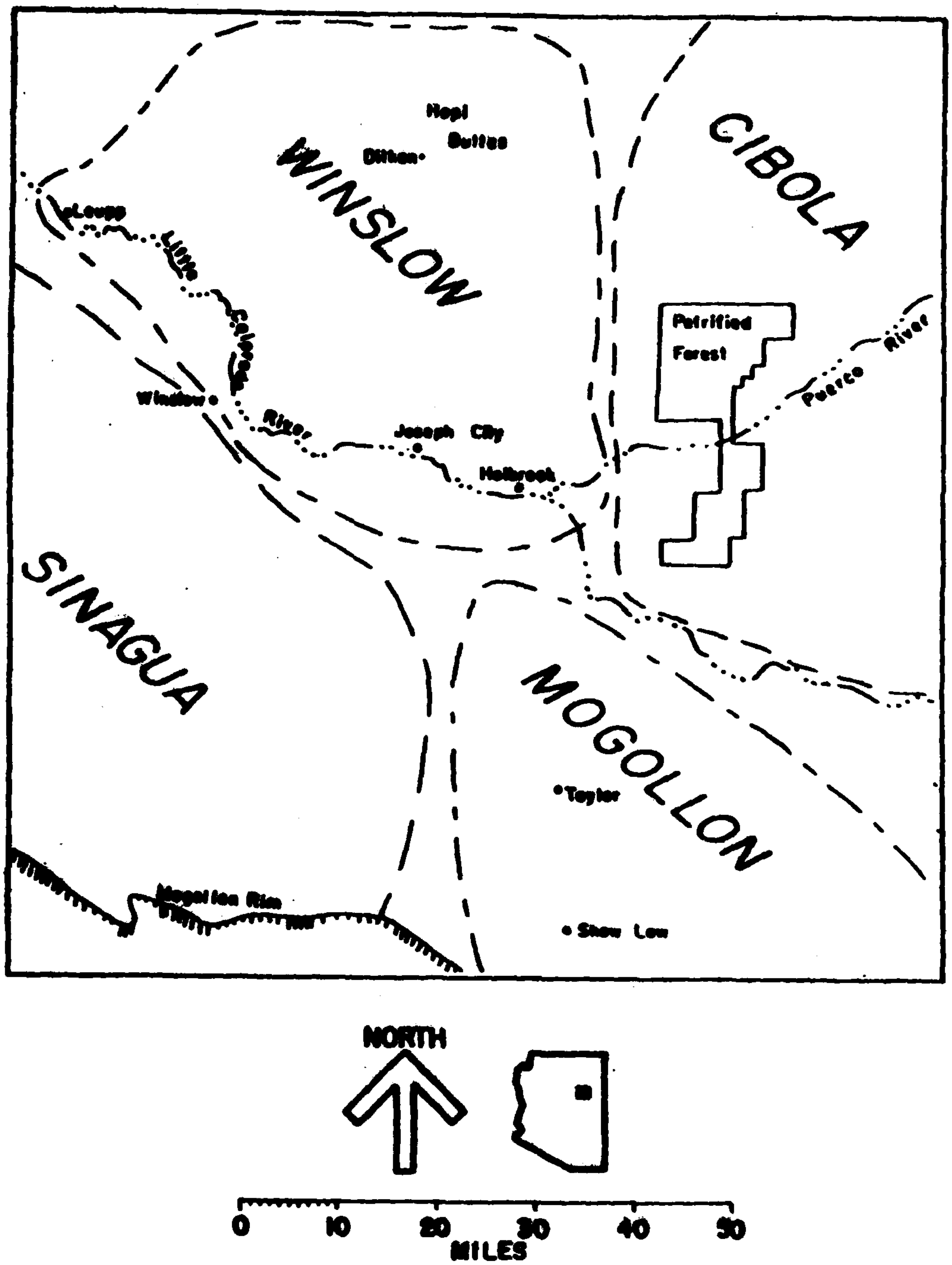


Figure 4. Culture Areas of the Little Colorado Region

Basketmaker II:

It is during this time period, approximately 100 B.C. to A.D. 400, that the Anasazi make their transition from a hunting and gathering subsistence base to an agricultural one. Basketmaker II sites in the general area of the middle Little Colorado include three sites which have been excavated by the Museum of Northern Arizona. The Flat Top Site, excavated by Fred Wendorf (1953) at the southern tip of Petrified Forest National Monument, is a pit house village with strong Mogollon influence dating prior to A.D. 600 and perhaps as early as A.D. 300. Another Basketmaker II site, NA6588, at the northern end of the Petrified Forest has been dated as pre-A.D. 500 (Breternitz 1956: 10-11). Finally, two pre-ceramic Basketmaker II pit houses excavated near Dilkon in 1966 seem to be basically Anasazi in character (Gumerman and Skinner 1968: 188). In sum, Basketmaker II sites found in the study area may exhibit Mogollon and Anasazi characteristics.

Basketmaker III:

The Basketmaker III Period, roughly A.D. 400 to 700, represents the next step toward a sedentary agricultural subsistence. Pottery comes into use at this time. Rabbit Hill Village (NA9577) (Rippey 1969) is a Basketmaker III - Pueblo I village near the junction of the Little Colorado River and Cottonwood Wash just east of Winslow. At this time, pottery is becoming predominantly Kayenta Branch Anasazi, as at three sites

recorded in the southwest Hopi Buttes area (Gumerman 1969: 114). A differentiation, then, between the central Little Colorado and areas to the east is seen by now, as demonstrated by the fact that the Twin Buttes site in the Petrified Forest belongs to the White Mound phase of the Cibola Branch of the Anasazi culture (Wendorf 1953: 160).

Pueblo I:

It is possible that the Kayenta people and the inhabitants of the central Little Colorado shared the same Kayenta-type structure during Basketmaker III, Pueblo I, and early Pueblo II times (Gumerman and Skinner 1968: 189). Anasazi-Mogollon contacts, however, are still evident in Pueblo I sites excavated in the central Little Colorado Valley. During the Pueblo I and II periods, A.D. 700 to 900 to 1100 respectively, a transition occurs from pit houses to above-ground, masonry pueblos. Examples of Pueblo I sites are the Kol site (NA9182) in the Hopi Buttes region north of the river (Gumerman 1969: 149-176), and NA6583, about 7 mi. east of Winslow (Breternitz 1957: 8-10), which Breternitz feels illustrates trade contacts between the Anasazi, Mogollon, and Hohokam. No positive evidence has been discovered of Pueblo I occupation within the study area to date. However, there is no apparent reason for believing that Pueblo I utilization of the area did not occur.

Pueblo II - The Holbrook Phase:

During Pueblo II times in the central Little Colorado, localized variation begins to appear. The Winslow branch is now recognizable as a district entity within this area (see Fig. 4). Five early Pueblo II sites, A.D. 900 to 1075, recorded in the Hopi Buttes area are almost pure Kayenta sites. However, the transition from Kayenta to Holbrook phase ceramics and architecture can be seen at the Wigwam site (NA9092), near Holbrook. An increase in population seems to have accompanied this transition, and a widely dispersed settlement pattern with flood water farming prevails (Gumerman and Skinner 1968: 189-90). The Holbrook phase seems to last only from A.D. 1075 to 1100.

Pueblo III - The McDonald Phase:

The McDonald phase is defined by the widespread occurrence of large apartment-type towns. Between A.D. 1100 and 1250, sites from this phase occur in the central little Colorado River Valley. Examples include 146 sites recorded in the southwest Hopi Buttes area (Gumerman 1969: 114), and three excavated sites at Holbrook (Gumerman and Skinner 1968: 192). Pueblo III sites in the central Little Colorado area are more numerous than Pueblo II sites, possibly representing a population increase; are slightly larger; and are still evenly dispersed (Gumerman and Skinner 1968: 191). The Sundown site (NA9093) at Holbrook and the Plaza site (NA9400) in the Hopi Buttes area, are quite unusual, in that

they are large, well-built, plaza-type sites, and may represent the beginning of inter-site ceremonial gatherings.

Pueblo IV:

By about A.D. 1250, most of the drier areas of the central Little Colorado area were abandoned, as people gathered into large pueblos along the river and probably on the Hopi Mesas. These pueblos are generally known as "proto-Hopi" sites, the implication being that present-day Hopis are derived from them, at least in part. Several examples of this type of site may be found in the literature. Perhaps the best known are the Homolovi group (NA952, NA953, NA4089, and NA926) near Winslow, and the Chevelon Ruin (NA1026) east of Winslow. These were explored by Jesse W. Fewkes in the late 1890's (Fewkes 1904: 25-30). An unexcavated Pueblo IV site, NA10,569, is located west of Joseph City. The Puerco Ruin (NA6302), near the junction of the Little Colorado and Puerco rivers, is another Pueblo IV site in the area (Schroeder 1961). Finally, the Chimney Butte site (NA9181) in the Hopi Buttes region has been excavated (Gumerman 1969: 291-304). Each of these sites has Hopi-like petroglyphs in its vicinity.

Cibola Branch

Cibola White Ware, the diagnostic pottery of this neighboring Anasazi group (see Fig. 4), has been found in the central Little Colorado region. Gumerman reports finding

much Cibola White Ware in the Hopi Buttes area during the Basketmaker III period, with amounts lessening as time progresses and contacts with the east lose importance (Gumerman and Skinner 1968: 197). It can perhaps be assumed that a similar situation will hold for the entire central Little Colorado area.

Sinagua

Almost no evidence of Sinagua influence has been found in the central Little Colorado Valley. Gumerman (1969: 374) reports only a handful of Sinagua sherds, a possible Sinagua-influenced kiva, and Sinagua-like extended burials during his southwest Hopi Buttes survey and excavations. However, he feels that there must have been extensive contact between the two groups because of the large numbers of Little Colorado White Ware sherds found near Flagstaff. Wilson (1969: 43) states that Sinagua sites do not extend as far east as Chevelon Creek, and that the area between East Clear and Chevelon Creeks may be considered a cultural boundary. However, his survey did not extend north as far as the Little Colorado Valley.

Navajo

Navajo Indians are known to have lived in the middle Little Colorado region. Gumerman came upon recent Navajo sites and Navajos who were presently living in the area

while conducting his southwest Hopi Buttes survey (Gumerman 1969: 20), and the early Mormon settlers reported having Navajos for neighbors (Westover and Richards 1963: 7). Stories are also found in the literature about Navajo raiding in the area (Jennings 1970: 73 and Johnson 1956: 38).

Western Apache

The literature regarding the pre-1800's Apache lacks clarity. However, there are indications that the possibility for Apache occupation of the middle Little Colorado River Valley does exist. Historical literature would indicate that no Navajo or Apache activity took place west of the Rio Grande prior to the 17th century. However, Grenville Goodwin has recorded many clan origin stories among the Western Apache which indicate a southward movement of the Western Apache from Hopi country to the present Mogollon Rim northern boundary. In myths of all five Western Apache groups, there exists the claim of having long ago lived at a place with the Navajo, Hopi, and others. Further Goodwin specifically states, "...at least a part, if not all, of the Western Apache were at some time living in the Little Colorado Valley to the north of their historic range" (Goodwin 1942: 66). Goodwin's answer to the lack of contact between early Europeans and the Western Apache is that Apache camps are well-hidden, and that Apache tended to hide from the Spanish (Goodwin 1942: 66). There is no doubt that the Western Apache have had much

contact with the Hopi. Much has appeared in the literature about trade between the two groups.

Dates for possible Western Apache occupation of the central Little Colorado are as difficult to come by as definite proof of the occupation itself. Jack D. Forbes (1966: 345) feels that they were in the area (in fact, that they reached the Mogollon Rim area) by the late 1300's. In the late 1700's little information exists from historical data about the northern Apache boundary, except that the Apache were "to the south of the Hopis" (Schroeder 1963V-A: 29-30). By the 1850's, Western Apache territory ended at the north slope of the Mogollon Rim (Goodwin 1942: 65). By the late 1870's, the Mormons of the middle Little Colorado settlements did not even consider the Western Apache to be their neighbors (Westover and Richards 1963: 7).

In summary, early Western Apache occupation of the middle Little Colorado River area is a distinct possibility, and pre-1850 Western Apache sites could conceivably be found within the area.

<u>Recent History of the Middle Little Colorado River Valley</u>

The events which have been most influential to the central Little Colorado area during historic times are the Beale Wagon Road, the Atlantic and Pacific Railroad, cattle ranching, and Mormon settlement. All four of these influences are related and interwoven, but an attempt will nevertheless be made to

discuss each separately.

Beale Wagon Road:

As it became more and more important to establish lines of communication between the eastern and western parts of the United States, surveys were sponsored and sent out to discover the best east-west routes. Some of these explorations touched on the area with which this project is concerned.

In 1851, Captain Lorenzo Sitgreaves traveled across Arizona from New Mexico, following the Zuni and Little Colorado Rivers until he reached the Mohave villages on the Colorado River. Two years later, Lieutenant A. W. Whipple of the U. S. Army discovered an east-west route across Arizona which closely followed the 35th parallel, just north of Joseph City. Finally, in 1857, Edward F. Beale made a wagon road survey which resulted in the first truly practical east-west route. The Beale Wagon Road was used for almost all east to west crossings of Arizona until the coming of the railroad (Wahmann 1971: 6). Adele Westover and J. Morris Richards (1963: 32) mention an "old trails highway" which used to pass Joseph City on the south side of the river. This probably was not the Beale Wagon Road, which passed Joseph City north of the Little Colorado (Wahmann 1971: 9). It may, however, have been what Charles Peterson refers to as the Mormon wagon road, which followed the Little Colorado on the south until reaching Holbrook (Peterson 1967: 143-6). When U. S. Highway 66, which generally

follows the Beale Wagon Road in the Holbrook area was constructed, the road was re-routed to pass through Joseph City.

The Atlantic and Pacific Railroad:

In 1880, construction began on the western continuation of a railroad from the east which had previously ended at the Rio Grande River in New Mexico. This railroad line was called the Atlantic and Pacific Railroad, later to become the Atchison Topeka and Santa Fe, and closely followed the Beale route (Wahmann 1971: 9). The railroad was of great importance in the transportation of cattle. Because of this traffic, Holbrook became a regional shipping center, and Winslow a division headquarters for the railroad. The train stopped at Joseph City itself, as well as at numerous section houses. One of these was Hardy, later called Havre, near Joseph City (Barnes 1960: 239).

In 1881, the railroad construction came to Joseph City, then called St. Joseph, and a railroad camp was set up 1 mi. east of the town. Mormon men were hired to help in the construction (Westover and Richards 1963: 25), hauling rock from a quarry at Penzance (Barnes 1960: 247).

Cattle:

As cattle raising became an important venture in northern Arizona in the late 1800's, its effect was definitely felt in the Holbrook-Winslow area. Holbrook, as mentioned previously, was a large cattle shipping center. Even Mormon farmers have

been involved in ranching in this area. For example, in the early 1900's Henry De Spain, son of a Joseph City founder, bought the Old Rope Ranch, 4 mi. west of Holbrook, south of the Little Colorado River (Westover and Richards 1963: 171).

In the 1880's, however, the business was dominated by large cattle companies owned by eastern businessmen. One of the most famous of these large cattle companies was the Hash Knife "outfit", owned by the Aztec Land and Cattle Company. The Hash Knife spread did exactly that - over 52,000 sq. mi. of Arizona and New Mexico. Its borders were 650 mi. long and 80 mi. wide and included the area south of the Little Colorado River (Johnson 1956: 4). In approximately 1881, the Aztec Company's headquarters consisted of an adobe building at Obed, an early Mormon settlement just 3 mi. south of the present Joseph City (Jennings 1970: 32). Much folklore is connected with the Hash Knife and its employees, including a book about Burt Mossman (Hunt 1951), the manager who made a brave attempt to hold the outfit together at its end. In 1900, beaten by a combination of over-grazing, drought, rustling, poor prices, and the severe winter of 1892-99, the company sold out to Barney Stiles, Charlie Wyrick and the Babbitt brothers (Hunt 1951: 139 and Johnson 1956: 39).

Mormon Settlement:

In 1873, members of the Mormon faith were sent by Brigham Young in Utah to colonize the Little Colorado River. In May

of that year, the first group reached the river, but turned back. In October of 1875, a second group set off to explore the valleys and tributaries of the river. They returned to Salt Lake City by January, 1876, and on the basis of their favorable reports, four groups of 50 were sent off to make settlements, arriving 3 mi. east of Joseph City on March 24, 1876 (McClintock 1921: 135).

The group led by William C. Allen stayed at this place; while George Lake's group went approximately 4 mi. downstream and across the river, to establish the settlement known first as Lake's Camp, and later as Obed. Lot Smith and company also went downstream to Sunset Crossing near Cottonwood Wash, establishing Sunset, while Jesse O. Balinger's men set up Brigham City southwest of Sunset, near what is now Winslow (McClintock 1921: 135 and Westover and Richards 1963: 7). In July, Allen's Camp was moved to 1 mi. east of the present site of Joseph City and became known as Allen City. In 1952 a monument was erected at this site by the Daughters of Utah Pioneers.

Holbrook:

Holbrook, located at the junction of the Puerco and Little Colorado rivers, was founded in 1871. Originally named Horsehead Crossing, the town was renamed in honor of a railroad engineer, H. R. Holbrook. The original inhabitant, Juan Padilla, was well known for his hospitality and generosity. Holbrook swiftly grew as an important supply, railroad, and ranching town as well as a major travel intersection (Dreyfuss 1972: Navajo County; Barnes 1960: 240).

CULTURAL RESOURCE DESCRIPTION

No sites were discovered during the survey in any of the areas examined. The sole evidence of prehistoric materials in the area were four flakes of chipped stone found on a knoll top area in the eastern portion of the rechannelization corridor. These flakes were not deemed significant enough to be recorded as a site although their location was noted (Figure 1). Throughout the survey area fence posts, barbed wire fences, miscellaneous driftwood and planks, scattered modern historic trash, and faint traces of abandoned roads were observed. Virtually all of the material was obviously associated with relatively recent (within the last 50 years) ranching and farming activities. No historic remains warranting site designation were noted. In addition, site file searches at the Museum of Northern Arizona, Arizona State University, and Arizona State Museum indicated that there were no previously recorded sites in the project area.

There are several reasons for the paucity of cultural remains extant in the Little Colorado River floodplain. Among these is the fact that all areas in the floodplain are covered with large amounts of silt which would act to obscure the evidence of prehistoric and historic activities. The river channel itslef is subject to flooding twice each year which would wash away any cultural remains (Fig. 1). The river banks are subject to periodic flooding as well. As this

flooding would be less swift and violent than that occurring in the river bed itself, it would tend to deposit layers of silt over any cultural remains rather than washing them downstream. Also, even if cultural remains remained present on the ground surface, it is very unlikely that they would be visible, due to the dense vegetation cover in most areas which completely obscures the ground surface (Fig. 2).

In addition to the destructive nature of the floodplain environment on cultural remains, there is some doubt as to whether the floodplain area of this portion of the river would have been heavily settled prehistorically. The dense vegetation in the river bank areas would have made the construction of settlements difficult for a cultural group primarily adapted to the surrounding desert. Periodic flooding would also have discouraged the construction of permanent settlements. A third factor which may have inhibited settlement in the floodplain is that the area is infested with insects, especially mosquitos, which would have made living in these areas uncomfortable and unhealthy. Coupled with these factors is the fact that the floodplains are surrounded by areas, primarily old river terraces, which are eminently more suitable for the placement of sites such as were occupied by the prehistoric peoples found in the Little Colorado Valley.

METHODS

A total of 11.6 linear miles of proposed rechannelization and associated levees were visually examined during the survey. Survey methods employed were as follows: In the river channel areas, having a width of 300 feet, the three person crew would walk along one side of the corridor spaced at intervals of 50 feet. In this way, half of the corridor could be examined on a single pass. After walking one side of the corridor for a distance of one or two miles, the crew would turn and walk back along the other side of the corridor. Rigid 50 foot spacing could occasionally not be maintained due to heavy vegetation growth (Fig. 2). This spacing, however, was adhered to the great majority of the time.

Levee areas were surveyed in much the same way except that as these areas were only 50 feet wide, the areas could be examined in a single pass. Spacing of the crew members was approximately 15 feet.

Location of the corridor and levees and the position of the survey crew were determined through the use of aerial photographs supplied by the Corps of Engineers and U.S.G.S. 7.5' topographic maps.

One small area measuring less than 0.1 mile on a side could not be surveyed (Fig. 1). This area was located in the midst of a group of houses and it was felt that surveying the area would constitute trespassing and an unnecessary

invasion of the privacy of the inhabitants of the houses. The area appeared to have been disturbed by grading and house construction at some time in the past and is now heavily overgrown with vegetation as well.

Photographs were taken of various portions of the project area (Figs. 2-3), as well as notes on the project area physiography and vegetation.

The Arizona and National Registers of Historic Places were consulted. The proposed project area does not contain any historic or archaeological sites that appear on or are being nominated for inclusion in those registers. It should be noted that Native American groups were not consulted because no cultural resources were encountered and no subsurface tests were conducted.

RECOMMENDATIONS

As no sites were discovered in the areas proposed by the Corps of Engineers for rechannelization or levee construction, it is not deemed necessary to carry out further archaeological investigations prior to the initiation of construction activities. As outlined above, it is possible that cultural resources could exist below the present ground surface in the Little Colorado River floodplain. It is recommended for this reason that a program of archaeological monitoring be carried out in conjunction with proposed construction. This would involve (1) advising the construction contractor of the possibility of subsurface cultural remains and (2) the periodic inspection of construction activities by a qualified archaeologist to determine whether cultural remains are indeed being unearthed. This monitoring program should be more intensive for areas such as knoll tops and proposed levee areas away from the river where the likelihood of discovering cultural resources is somewhat higher than in the river bed areas.

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1969 The Sinagua and Their Neighbors. Ph.D. Dissertation, Harvard University, Cambridge.

APPENDIX I

Literature Sources

The following is a list of literature sources consulted, in addition to those listed under references cited, to gather data pertinent to the study area:

Fish, Paul R.
1974 The lithic remains found in the proposed ash dump areas of the Cholla Power plant. Manuscript on file at the Museum of Northern Arizona. Flagstaff.

Gumerman, George J. and Robert L. Sutton
1967 An Archaeological Approach to Recent Environmental Changes in the Southwest Hopi Buttes Region, Arizona. Manuscript on file at the Museum of Northern Arizona, Flagstaff.

Keller, Donald R.
1975 Final report for the inventory survey of three parcels of federal land in the Cholla Power Plant expansion ash disposal area. Manuscript on file at the Museum of Northern Arizona. Flagstaff.

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Metcalf, Michael D., Howard M. Davidson and Kathleen E. Moffitt
1974 Preliminary draft for phase I archaeological and ethnohistorical research, Arizona Station Transmission System. Manuscript on file at the Museum of Northern Arizona. Flagstaff.

Pilles, Peter J. and Pamela Haas
1973 A preliminary draft for phase II archaeological and ethnohistorical research consultation for the Cholla Power Plant proposed expansion program. Manuscript on file at the Museum of Northern Arizona. Flagstaff.

APPENDIX II

Man-Hours Expended

The following is a breakdown of time spent during various phases of the survey project:

Literature Search--8 hours

Field Survey------72 hours

Report Writing----20 hours

APPENDIX III

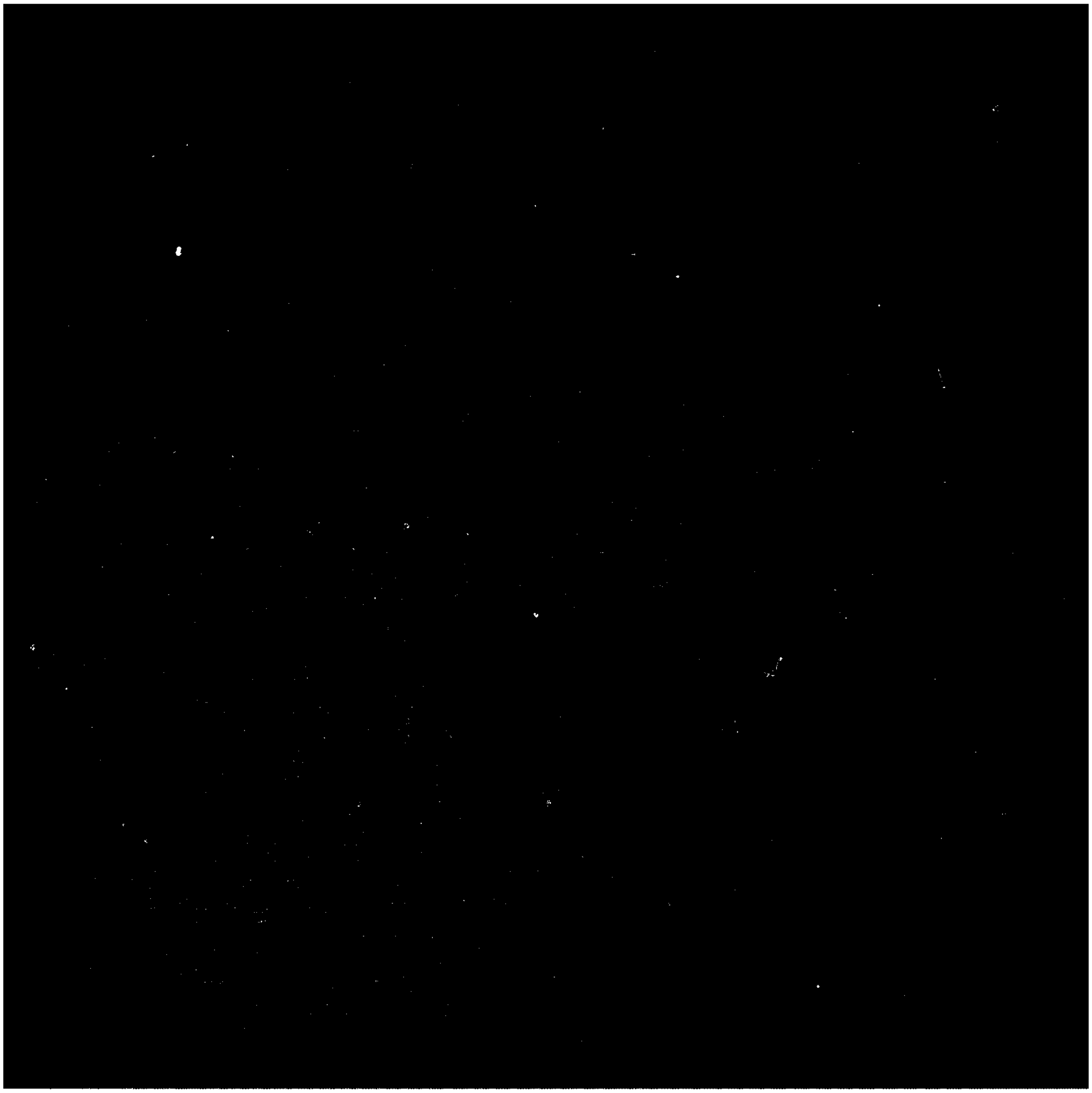
Agencies Contacted

The following persons were contacted in coordination with the record search for possible previously recorded sites in the project area:

Renee Popey, Archaeology Laboratory
Department of Anthropology
Arizona State University
Tempe, Arizona 85281

Sharon Urban
Department of Anthropology
Arizona State Museum
Tucson, Arizona 85721

Arizona State Historic Preservation Officer
Arizona State Park Board
Phoenix, Arizona 85007



Section D

DESIGN AND COST

CONTENTS

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SECTION D

DESIGN AND COST

GENERAL

1. This section provides background material on the design and cost estimates of the detailed plans studied, the single-levee, double-levee, and flood-proofing plans. It also provides plan and profile sheets for the tentatively selected plan, the double-levee plan. An extensive description of the elements of the plans can be found in Section B, "Formulation, Assessment, and Evaluation of Detailed Plans."

2. The levee plans include an 80-ft base width, trapezoidal low-flow channel with 1V:3H side slopes, and selective clearing of the streambed, 1,000 ft wide, extending through the project reach. The low-flow channel would be comparable to a recently excavated channel by local interests.

Regional Topography and Geology

3. The river bed at Holbrook is generally wide and flat consisting mainly of fine alluvial sands and sporadic clayey silt lenses. The underlying bedrock in the area consists mainly of Permian and Triassic age sandstones. North of the town, a belt of Triassic conglomerate occurs. The terrain near Holbrook is comparatively flat, although numerous, small, low-lying hills occur within the area. For many miles in extent, the region surrounding Holbrook is a part of the Mogollan Plateau, which is part of the Colorado Plateau province. The distinguishing features of this province are the nearly horizontal rock formations, the high altitude of the land surface and the development of numerous canyons despite the general aridity of the region.

Groundwater

4. Based on the well water depth recordings listed in Table D-1, for the wells located on Plate D-5, it appears that groundwater will be encountered at shallow depths. Groundwater depths along the project reach will be evaluated with greater certainty during future design studies and their related subsurface investigations.

Table D-1. Observed Well Data

Well Date	Ground Elevation	Location	Depth to Water	Water Elevation	Thalweg Elevation
4/66-1	5165	3 1/2 miles SE of Holbrook	-54 ft	5111	5110
11/72-2	5080	3 miles W of Holbrook	-33 ft	5047	5048
3/68-3	5090	5 miles SW of Holbrook	-39 ft	5051	5055

Based on U.S.G.S. 15 min quad of Holbrook, Arizona.
See Plate 1 for well locations.

Seismicity

5. The project arc is in Zone II on the Seismic Zone Map of the United States (Ref. ER 1110-2 30 Apr 1977) and is considered a moderate risk region. The largest known earthquake in the State's history was one of epicentral intensity VIII (modified Mercalli) recorded in 1910 approximately 75 miles northeast of Flagstaff. Structural features and locations of earthquake epicenters in Arizona are given on Plate D-6. Pseudo-static anaysis of the levee slopes during the design of the levee should be adequate to insure the stability of the structure.

LEVEE PLANS

Design

6. The preliminary hydraulic design for the levee plans was based on criteria and procedures presented in EM 1110-2-1601 and applicable engineer technical letters. Because of the similarity of the levee plans, specific design data is provided only for the tentatively selected plan, the double-levee plan. In addition to the structural elements of the single-levee plan, the double-levee plan includes the south levee and south interior drainage channel and an additional one foot in the height of the levee.

7. Since the construction of the existing Holbrook levee in 1948; considerable aggradation has occurred in the project reach, rendering the project incapable of safely conveying the original design discharge of 60,000 cfs. Consequently, the design of the proposed plans in this report entailed detailed analysis of past sediment deposition and a projection of future sediment deposition in the study area. Based on these studies design allowances for future sediment deposition were incorporated into the proposed plans. The sediment problems are discussed in detail in paragraphs 22 through 35, inclusive.

8. Plates D-1 through D-4 present the plan and profile drawings for the tentatively selected plan, the double-levee plan. Plan and profile drawings are not included for the single-levee plan since design elements for this plan are similar to those of the double-levee plan. The water surface profile for the one-levee plan is about 1 foot lower than that of the tentatively selected plan. Water surface profiles for the SPF design discharge under future conditions (with sediment accumulation) are shown in Plates D-1 and D-4. The water surface profile for the 100-year discharge of 60,000 cfs under existing topographic conditions is also shown. The existing Holbrook levees was designed to convey 60,000 cfs with 2 feet of freeboard. The profile for 60,000 cfs, as presented in this report, indicates that the existing levee would be overtopped by this design discharge under existing conditions.

9. Water surface profiles were computed by the reach method using the Manning formula. The computerized procedure contained in the HEC-2 Water Surface Profile (No. 723-02A) computer program, developed by the

Hydrologic Engineer Center, U.S. Army Corps of Engineers, was utilized. Contraction and expansion coefficients of 0.1 and 0.3, respectively, were applied. Four feet of debris on each bridge pier was assumed in the hydraulic analysis for all of the bridges.

10. Roughness coefficients ranging from "n" = 0.035 for relatively growth-free areas to "n" = .06 for areas with dense phreatophyte growth were applied. From the Puerco River to Leroux Wash the phreatophyte growth is sparse to medium, with small areas of dense growth. Studies were also conducted to determine the impact of changes in "n" values on water surface elevations. Assuming total channel clearing within the project reach and using an "n" value of 0.035, the depth of flow would be about 0.8 feet less upstream of the highway bridge and generally about 0.3 foot less in the downstream reach as compared to depths of flow under existing (1973) conditions.

11. Water surface profiles were computed with uniform sediment deposition of 4 feet upstream from the highway bridge and 1.5 feet downstream from the railroad bridge. Sediment distribution between the bridges was assumed to vary from 4 to 1.5 feet.

Design Water Surface Profiles

12. Plates D-1 through D-4 present the design water surface profile. The design water surface profiles were determined by increasing the computed values (with future sediment allowance) by an additional 3.0 feet upstream of the highway bridge to account for the indeterminable effect of the bridge on major floodflows. Downstream of the highway bridge the computed values represent the design water surface profile. Flow velocities would generally range from 3 to 13 feet per second with the higher velocity occurring near the bridges.

Plan Elements

13. The following paragraphs discuss design criteria of the plan elements of the tentatively selected plan (double-levee plan).

14. LEVEES. The top of the levees above the water surface profiles indicated in plates D-1 through D-4 was determined by providing for a normal freeboard of 3.0 feet above the design water surface elevation. The proposed project was analyzed to determine the mathematical location where the levees would most likely be overtopped by floods greater than the design flood (SPF). The minimum discharge (about 140,000 cfs) at which the energy gradient would be at the top of levee would occur just upstream of the railroad bridge. Discharges at which the energy gradient would be at the top of the levee upstream from the highway bridge would range from about 130,000 to 160,000 cfs. Downstream from the railroad bridge the discharges would range from 165,000 to 190,000 cfs (energy gradient at top of levee). The energy gradients used in the analysis were based on computed values, with future sediment deposition, and allowing for an additional 3.0 ft. to account for the indeterminable effects of the highway bridge for the reach upstream from the bridge. Computed values with future sediment deposition were used downstream from the highway bridge.

15. It is probable that the channel would degrade at the bridges during major flood events because of the increased velocity at the constriction. Should this occur the discharge capacity would increase. The final determination on whether or not the levee height should be increased at specific locations along the project reach would be refined during detailed studies, at which time the sediment problem would be reevaluated based on data collected from the recently installed sediment sampling stations at Holbrook and at Penzance dam (see paragraph 35).

16. BRIDGES. The existing railroad bridge (570 feet long) would be replaced with a new bridge, 1,480 feet in length, and on 1.35-foot diameter piles with piers spaced 30 feet on centers. Flow would be class "B" with velocity of flow about 15 feet per second at the standard project flood discharge of 107,000 cfs. The deck elevation of the existing highway bridge (300 feet long) is at 5,079.6. The discharge of 107,000 cfs with future sediment deposition would overtop the bridge deck by about 8.6 feet.

17. MITER GATES. Miter gates, 18.5 feet in height, would be required at the north and south levees where Highway 77 crosses the river. The top of the miter gates would be set at the same elevation as the top of the levees immediately upstream of the highway bridge.

18. LOW-FLOW CHANNEL. The double-levee plan would include an 80-foot base width, trapezoidal low-flow channel along the alinement of the existing low-flow channel. Flows of 1500 cfs to 1800 cfs would be confined by the low-flow channel. The mean daily discharges exceed 2000 cfs about 24 days a year on the average. The proposed low-flow channel would enhance movement of sediments through the project area during smaller flows, and would also function as a pilot channel in directing larger flows and restricting meanders. Holbrook has recently completed excavation of a low-flow channel from the Penzance diversion dam to some distance upstream from the highway bridge. The low-flow channel is roughly 80 feet wide. Reports received by the Los Angeles District following a flood of about 12,000 cfs in the study area in August 1977 indicated that the low-flow channel showed no signs of silting but that the banks were eroded at some locations. After a flood of about 25,000 cfs in 1978, much of the low-flow channel had filled in with sediment. The filling-in of the low-flow channel is not an unexpected event. As discussed in a subsequent paragraph, the Corps of Engineers, in cooperation with the U.S. Geological Survey, has initiated a program for gathering and analyzing sediment data in the project area. The information gathered from this program, together with other information, such as the cost of maintaining the channel, will be used during advanced planning stages to reassess the necessity and value of this feature of the proposed plan.

19. CHANNEL CLEARING. One of the problems at Holbrook since construction of the existing levee has been the proliferation of vegetation, particularly salt cedar, in the streambed. To control this growth a 1000-foot-wide strip, about 15,540 feet in length, would be selectively cleared and maintained as a part of the project. The

proposed channel clearing is essential to help reduce the tendency for sediment to deposit on the streambed during floods that exceed the low-flow capacity. The strip would extend from the upstream limit of the project to about 6,700 feet downstream from the railroad bridge. The limits of the cleared strip are shown on plates D-2 and D-3. Existing cottonwood trees would be allowed to remain in the strip, both for environmental reasons and for their ability to shade and discourage lower, more dense growth such as salt cedar. The strip would also be seeded with grasses and smaller shrubs to discourage reentry of salt cedar. Within the limits of the designated cleared area, a 30-ft-wide strip of existing vegetation would be allowed to remain on each side of the low-flow channel approximately midway between the channel and the outer edges of the cleared strip. The uncleared strips would begin about 300 feet downstream from the proposed railroad bridge and extend downstream to the end of the cleared strip. These strips of existing riparian vegetation would provide diverisified wildlife habitat and would mitigate adverse impacts on the wildlife. Periodic maintenance would be required to remove new growths, including cottonwoods, from areas designated for removal of existing vegetation when the height exceeds 3 feet. Insofar as speed of growth of vegetation permits, maintenance mowing would be accomplished on a 3 year program with one-third of the cleared area being mowed each year. The rotational mowing program would permit a 2-year growth to provide wildlife cover.

20. STRUCTURAL DESIGN OF LEVEES. The foundation conditions are adequate for the proposed improvements. The materials are primarily fine alluvial sands with intermittent clayey silt lenses. Bedrock, generally consisting of sandstone, should not be encountered during toe excavation or pilot channel construction. The groundwater table is relatively high and may present problems for heavy construction equipment during construction of the channel. The levee embankments will require approximately 600,000 cubic yards of compacted fill. The embankment material will be compacted to at least 95 percent of maximum density (ASTM 698) at about optimum moisture content. Levee slopes will not be steeper than 1V on 2H. Design velocities, based on an "n" value of 0.028 (total clearing of the streambed), would range from about 3 feet per second to 8 feet per second alongside the levees. A minimum riprap thickness of 15 inches would be required to protect the levee slope. Toe protection for the levee would extend to an elevation equal to the toe of the existing revetments and to 10 feet below the river streambed at other locations. Grouted stonework (15 in. thick) would be required for levee slope protection beginning 200 feet upstream from the highway bridge to 200 feet downstream from the railroad bridge where velocities would range to 13 feet per second. The toe excavation for the cutoff may require dewatering depending on the groundwater levels during construction. Excavated materials may be stockpiled and used for the toe backfill operations. Compaction may be accomplished by controlled wheel loadings. A graded gravel filter blanket will be required beneath the riprap. A filter blanket 6 inches thick should be adequate.

21. **INTERIOR DRAINAGE.** Drainage structures were designed to control the 100-year (1-percent chance) peak discharge and/or volume from interior drainage areas with a coincident flow of 18,000 cfs in the river (see the discussion of the determination of coincident flows in Section F of this appendix "Hydrology," under the heading titled "Coincident flows").

22. A ponding area (plate D-3) would be excavated on the north side of the river just east of the old fairgrounds at a site where an existing uncompacted levee is presently used to retain tributary flows from east and northeast of Holbrook (areas A and E on pl. F-16). The ponding area, excavated to a depth of about 4 feet below general ground surface and with a surface area of about 59 acres, would retain the 100-year flood volume of about 234 acre-feet from the tributaries. The storage volume of the ponding area would be adequate to reduce outflows during floods larger than the 100-year to near non-damaging level. During a SPF on the east and airport tributaries (see plate F-20) flooding depths downstream from the ponding area would be about 0.7 foot. An outlet channel would connect the pond to an existing double 4 feet wide by 4 feet high box culvert through the Santa Fe Railroad embankment and the existing levee. The existing culvert would be extended as required with construction of the proposed levee.

23. An entrenched trapezoidal channel (pl. D-4) would be constructed along the landside of the south levee to drain tributary flows emanating from a small drainage area (area H on pl. F-16), most of which lies east of Route 77 and south of Montano Street. The channel, with a base width of 40 feet, depth of 7 feet, and 2 horizontal to 1 vertical side slopes, would be designed to carry the 100-year peak tributary flow of 960 cfs. A five-barrel concrete culvert with flap gates, each barrel 7 feet high by 8 feet wide, would be required at the Apache Railroad embankment.

24. A triple box reinforced concrete culvert (pl. D-4), with each box 6 feet wide by 5 feet high, would be required at the railroad embankment a short distance southwest of the proposed culvert for the trapezoidal channel. The culvert would be designed for a 100-year discharge of 530 cfs.

Sediment Studies and Design Allowances for Future Sediment Deposition

25. Considerable aggradation has occurred in the Little Colorado River from Penzance diversion dam upstream to its confluence with the Puerco River since construction of the existing levee in 1948. A number of reasons have been advanced to explain the substantial amount of aggradation in the study area. Some of these are: (a) deteriorating watershed conditions due to overgrazing; (b) phreatophyte growth in the streambed; (c) constriction at the existing bridge crossings; (d) sediment inflow from Leroux Wash, about 2-1/4 miles downstream from the railroad bridge; and (e) Penzance diversion dam, 2.75 miles downstream from the Leroux Wash confluence. Studies have indicated that items (d) and (e) have not contributed significantly to the buildup in sediment deposition upstream from the existing railroad and highway bridge.

26. A preliminary version of the HEC program, "Scour and Deposition in Rivers and Reservoirs," No. 723-G2-L2470, dated January 1974, was utilized to analytically compute the amount of future sedimentation in the study area. The attempt to model past aggradation in the streambed and to simulate future sediment transport in the study area was unsuccessful. In lieu of further efforts to develop and refine a mathematical model for sediment transport during the plan formulation stage, design allowances for future sediment deposition were based on past aggradation in the study area and engineering judgment. Eighteen cross-sections established during the Holbrook Levee study in 1939 were used as the basis for estimating past aggradation. Streambed elevations from 1973 topographic maps (1 in. = 200-feet scale and 4-feet contours) were superimposed on the 1939 sections. In addition, four of these cross-sections were surveyed in 1945 and in 1969. Examination of all these sections indicated that the streambed had aggraded about 4 feet upstream from the bridges and about 2 to 3 feet downstream from the bridges. Based on experiences with similar streams, the study area could probably be subjected to a cyclical process of degradation and aggradation. For design purposes a maximum additional deposition of 4 feet upstream from the bridges and 1.5 feet downstream from the bridges was projected for the study area within the project life of the proposed improvements. The sediment was assumed to distribute uniformly over the streambed. Future aggradation downstream from the bridges was estimated to be about half of past aggradation (using the upper limit of 3 feet for past aggradation). The flood plain downstream from the bridges is relatively broad, and the rate of increase in depth of deposition should tend to decrease as available area for deposition increases. The depth of sediment deposition was assumed to vary uniformly between the bridges.

Design Adequacy of Sediment Allowances for the Proposed Project

27. Inspection of stream profiles (fig. D-1) for the Little Colorado River at Holbrook reveals that 5 feet of sediment has deposited adjacent to Penzance diversion dam since 1939, decreasing to a depth of about 2 feet at Leroux Wash confluence (2.8 miles upstream from the damsite). The deposition at the damsite is an estimate only since the 1939 topography used for the previous Holbrook Levee Project extends from Holbrook to about 2.5 miles upstream from the damsite. The 1939 profile was extended to meet the apparent top of the diversion dam as it existed then in 1939 (elev. 5,029 feet) before the dam was eventually raised to its present sill elevation at 5,034 feet. The extension of the 1939 profile and the profile derived from the 1973 topography illustrates a wedge-shape deposit of 5 feet at the damsite (top of dam), varying to a depth of 2 feet at Leroux Wash. The sediment deposition varies from 1 to 3 feet from Leroux Wash to the crossings of the railroad and highway bridges in Holbrook. Wedge-shape deposits range from 4 to 2 feet from the bridge crossings to the upstream end of the proposed Holbrook Levee Project, with the higher depths prevalent immediately upstream from the bridges.

28. The average slopes of the streambed in 1939 and in 1973 (both are nearly equal) are as follows:

a. Penzance damsite to Leroux Wash (downstream reach): S = 0.0012.

b. Leroux Wash to bridges (middle reach): S = 0.0021.

c. Bridges to upstream end (upstream reach): S = 0.0013.

29. In analyzing deposition in the project area the following factors appear prominent:

a. Deposition at the downstream and upstream reaches is at about the same slope (S = 0.001).

b. In the middle reach, which is relatively wide and at a slope that is two times greater (S = 0.002 vs S = 0.001) than the downstream and upstream reaches, the amount of deposition is comparatively less and also is at the same streambed slope as existed in 1939 (S = 0.002).

30. Based on the discussion above and on engineering experience and subjective judgment, past and future sedimentation in the Little Colorado River at Holbrook is rationalized as follows:

a. The slope of the streambed stabilizes at about 0.001-the present slope in the upstream and downstream reaches. The 1939 slope for the same reaches was also at about 0.001. Sediment deposited upstream from the diversion dam and eventually stabilized at a slope of 0.001. Further aggradation of the streambed in the downstream reach is unlikely unless the dam is raised.

b. The wedge-type deposition in the downstream reach raised the streambed near Leroux Wash about 2 feet. The middle reach correspondingly aggraded almost uniformly to an equivalent depth of about 1 to 3 feet. No further aggradation is anticipated in the downstream reach; and, therefore, the middle reach should remain relatively free of further sedimentation. In all probability the middle reach would be subjected to degradation because of its relatively steep slope.

c. Aggradation in the upstream reach was induced by the constricted bridge crossings. Deposition eventually stabilized at S = 0.001. Since the proposed project does not require the removal of the highway bridge (the railroad bridge is to be raised and exended), additional deposition could be induced in the upstream reach. The design of the proposed levees allows for an additional 4 feet of sediment deposition in the upstream reach distributed uniformly over the streambed upstream from the highway bridge. The slope of the deposition would be at about 0.001 or similar to the existing streambed slope, and the assumed deposition would raise the streambed generally at or above

the grade of the approach road to the highway bridge. Considering that the upstream slope would be stable at about 0.001, and that sediment deposition induced by the constricted bridge crossing would probably maximize at the grade of the approach road, and that orifice flow through the bridge opening constitutes only about 10,000 cfs or 9 percent of the design discharge (the bulk of the flow is over the approach road and bridge deck), it is concluded that the 4-feet allowance for future sediment deposit would provide adequate assurances that the integrity of the proposed improvement would be maintained for project life. Sediment outflow from the project area should at least equal sediment inflow into the project area under design conditions. The presence of the proposed low-flow channel and the proposed selective clearing should further enhance the sediment transport capability in the upstream reach.

31. The study of sediment transport in the study area involves subjective judgment. Inadequacies inherent in such a study should be properly accounted for in the design of the proposed improvements. Obstructions and uneven distribution of sediment could result in variances in the computed water surface elevation. Therefore, in determining the design water surface profile upstream of the highway bridge the computed water surface elevations were increased 3.0 feet to account for the indeterminable effects of the existing highway bridge. Also, an allowance of 1.5 feet for future sediment deposition downstream from the bridges should reasonably account for the uncertainties that are of lesser extent than the upstream reach.

32. The proposed improvement was tested to determine whether sediment deposition and/or aggradation would occur during the ascending and descending limbs of the SPF hydrograph. The design allowances of 4.0 ft and 1.5 ft of deposition upstream and downstream of the bridges, respectively were assumed as the initial condition at the occurrance of the SPF.

33. The modified Du Boys equation, based on rationale and methodology developed by LAD to predict scour and deposition for a channel reach between two drop structures, was applied in analyzing the sediment transport capabilities of the proposed project. The problem area was divided into four reaches. Fig. D-2 presents pertinent information on the relationship of the assumed profiles for the reaches and the past and present stream profiles. Table D-3 presents the hyrologic, geometric, and sediment data.

34. Reach 1 referred to as the "dummy reach," is a mathematical tool used to generate a sediment load into the study area. The assumption is made that sediment load inflow equals the sediment load outflow for the dummy reach. Since the LAD method for analyzing rate of sediment transport applies to a uniform reach of channel between two drop structures, controls had to be established for each reach. These controls, particularly for Reach 2 and Reach 3, were selected to reflect as nearly as possible the streambed conditions. For Reach 2 the control was set at the highway bridge (about sta. 294+00) where there is a

pronounced break in the gradient. For Reach 3 the control was set at Sta. 240+00 for a similar reason. Reach 4 is an artificial channel intended to duplicate a channel with the same general invert slope as the prototype. This reach was inserted primarily to monitor the sensitivity of the downstream reach to sediment load passing the control at Sta. 240+00.

35. The Combined Sediment Transport computer program (722-G1-L1-015) was used in the solution of the modified Du Boys equation for rate of sediment transport. A summary of the results obtained from the sediment study is shown in Table D-4.

36. The results of the sediment transport study shown in Table D-4 could be converted to an "average depth" basis as follows:

TABLE D-2

AVERAGE DEPTH OF AGGRADATION*

REACH	AT SPF PEAK DISCHARGE	AT END OF SPF
1	(DUMMY REACH)	(DUMMY REACH)
2	0.3 ft.	0.4 ft.
3	-1.3 ft.	-1.5 ft.
4	0.4 ft.	0.5 ft.

* Aggradation in Reach 2 and Reach 4 and degradation in Reach 3 continuous during ascending and descending limo of the SPF hydrograph.

TABLE D-3

GEOMETRIC & SEDIMENT DATA

REACH	Trapezoidal section Base width (ft)	Side slope (hor:vert.)	Average invert slope (ft/ft)	Length (ft)	"n"	Mean size sediment (mm)
1	1000	2 : 1	.00140	15,000	.035	.3
2	1400	2 : 1	.00133	8,000	.035	.3
3	2000	2 : 1	.00210	6,000	.035	.3
4	3000	2 : 1	.00121	22,500	.035	.3

HYDROLOGIC DATA

Standard Project Flood "Stepped" Hydrograph

DURATION (HRS)	DISCHARGE (CFS)	DURATION (HRS)	DISCHARGE (CFS)
4	1000	2	57000
4	5000	2	54000
2	17000	2	42000
2	31000	2	32000
2	53000	2	26000
8	65000	4	19000
2	78000	4	11000
2	92000	4	7000
2	105000	4	5000
2	103000	8	3000
2	84000		

TABLE D-4

SEDIMENT LOAD IN CU. YDS.

	SPF PEAK (107,000 cfs)			END OF SPF HYDROGRAPH		
REACH	INFLOW	OUTFLOW	NET CHANGE IN VOLUME	INFLOW	OUTFLOW	NET CHANGE IN VOLUME
1	-	1,397,800	0	-	2,056,600	0
2	1,397,800	1,265,000	132,800	2,056,600	1,891,000	164,800
3	1,265,000	1,845,700	-580,700	1,891,000	2,575,300	-665,500
4	1,845,700	924,100	921,600	2,557,300	1,362,300	1,195,000

NOTES:

(1) Reach 1 is "dummy reach"

(2) Aggradation occurs in Reach 1 and Reach 4 during ascending and descending limb of hydrograph.

(3) Degradation occurs in Reach 3 during ascending and descending limb of hydrograph.

(4) Initial condition reflects 4.0 ft. and 1.5 ft of sediment deposited on streambed upstream and downstream of the bridges, respectively, prior to occurrance of SPF.

37. The aggradation that would occur during the occurrence of the SPF would be within tolerable limits of the 3.0 ft. normal freeboard for the levees.

Future Sediment Transport Studies

38. The Corps of Engineers has initiated, in conjunction with the U.S. Geological Survey, a program to measure and analyze sediment discharge in the Little Colorado River at Holbrook, Arizona. Automatic sediment samplers have been installed at Penzance Dam near Joseph City and at the highway bridge in Holbrook. These automatic samplers have been in operation since June 1979. In addition, a crest-stage gage has been installed at the highway bridge on Leroux Wash where the USGS would collect suspended sediment samples. The sediment data would be utilized during detailed design studies to reevaluate sediment transport in the project and mathematically define, with the use of the HEC-6 computer program, sediment deposition and/or aggradation in the Little Colorado River. Availability of physical data to determine sediment load would enhance the calibration of a model to simulate sediment transport in the study area and to minimize the many uncertainties relating to sediment movement in the design of the proposed project.

Construction

39. CONSTRUCTION PERIOD. Construction of the levee plans would require about 9 months. The esimated construction time assumes a continuous operation. Since freezing winter temperatures and high summer temperatures occur at Holbrook, the placing of concrete should be planned for periods of mild weather. Holbrook experiences both summer and winter rains; however, the primary rainy season is the summer, with most peak flows occurring in the months of July through October. Avoidance of these months to the extent possible in scheduling construction would be advantageous.

40. MATERIAL SOURCES. Sufficient quantities of borrow materials may be obtained from designated borrow areas along the northern foothills bordering Holbrook, see Plate D-5. Borrow site investigations, conducted in the project area, for the original Little Colorado River levee project by the Los Angeles District in 1945, indicate layers of clayey silt and silty sand, overlain by a layer of gravel along the northwest foothills. A similar soil profile is expected in the designated borrow areas. Native streambed materials consisting mainly of fine uncompacted alluvial sands are unsuitable for use in construction of the levee. Pending further site investigations, materials from the proposed 59-acre ponding area east of the Old Navajo County Fairgrounds may provide additional borrow fill. Excavation of the north-side pond and the south-side drainage channel would supply about 17 percent of the required fill material for levee construction. The amount of concrete required is small--less than 900 cubic yards--and can probably be supplied by local plants. Gravel of adequate gradation and quantity will be obtained from the designated borrow areas along the northern foothills bordering Holbrook. Medium hard sandstone can be obtained from the quarry at Penzance siding located approximately 5 miles west of Holbrook. Based on testing done by the Los Angeles District in December of 1976, the quarry rock was found to be a medium hard sandstone that will provide adequate slope protection.

41. COST ESTIMATE. The estimated first cost of the levee plans includes estimates for construction, rights-of-way, relocation of people and utilities, recreation, and beautification. Allowances for contingencies, engineering and design, and supervision and administration of construction are also included in estimated first costs. Unit prices were developed using September 1979 material, equipment, and labor costs typical of the study area. Detailed cost estimates for the levee plans are shown in Tables D-5 and D-6. Rights-of-way costs are estimated fair market value for interests which must be purchased (September 1979) based on an analysis of sales information and inspection of the lands involved.

Operation and Maintenance

42. Operation and maintenance of the proposed project would be the responsibility of the City of Holbrook and would include, but would not be limited to: (a) any repairs necessary to maintain the integrity and functionality of the levees and other drainage structures provided as part of the project, including removal of sediment from the northside pond; (b) removal of any large sediment deposit near the Leroux Wash confluence that inhibits the ability of the project to function as designed, whether the deposit originates from Leroux Wash or the Little Colorado River; (c) establishment and administration of a plan for operating the miter gates, including the designation of responsible personnel and periodic drills; (d) operation, maintenance, and replacement of recreational facilities; (e) removal of vegetation from the cleared strip when it exceeds 3 feet in height; and (f) overseeing and regulating the land within the easements and rights-of-way acquired for the proposed project so that no construction or other use impairs the functional capacity of the project.

43. Operation and maintenance costs for the project are estimated at $59,000 annually ($49,000 for flood control; $10,000 for recreation).

FLOOD PROOFING PLAN

Design and Cost

44. Design and costs for flood proofing structures in the flood plain were based on costs established by house movers, average architectural fees, and code established by the booklet, "Elevated Residential Structures," published by the Department of Housing and Urban Development. The cost of raising an average single family residence is estimated at $19,400. (See table D-7.) Design is based on an average 1500 square foot house on a foundation. Houses on slabs would cost an additional $5,300 per house. Structures would be raised an average of seven feet above ground level (see pl. B-7).

45. The above costs would be for single family houses to be raised. Costs would vary depending on the size of any type of structure. Structures flooded by SPF depths of less than two feet would be protected by a floodwall encircling the structure. Structures flooded by depths greater than 2 feet would be raised and a new

foundation would be built. Table D-8 displays the total cost for the flood proofing plan.

Operation and Maintenance

46. Operation and maintenance costs were not estimated for the floodproofing plan. These costs are assumed a part of normal operation and maintenance of a household and incremental costs were not calculated.

TABLE D-5. Cost Estimate -- Little Colorado River
Holbrook, Arizona
Single-Levee Plan
(September 1979 prices)

Description	Unit	Quantity	Unit Price	Amount	Subtotal	Total
Flood Control						
North Levee						
Clearing (Levee const)	Acre	59	700	41,300		
Diversion & Water Control	Job	1	L.S.	29,600		
Clearing water course	Acre	83	700	58,100		
Toe Excavation	CY	131,900	1.19	157,000		
Borrow Excavation	CY	441,400	1.42	626,800		
Compacted Fill Levee	Cy	388,400	.42	163,100		
Compacted Back Fill Toe	CY	98,900	.53	52,400		
Facing Stone	CY	57,300	11.86	680,000		
Bedding Stone	CY	22,900	12.45	285,100		
Cement	CWT	7,300	6.20	45,000		
Grout	CY	970	35.57	34,500		
A.C. Pavement (Service Rd)	Ton	2,500	21.34	53,400		
Subtotal					$2,226,300	
Remove Concrete	CY	180	47.43	8,500		
Miter Gate (Hwy 260)						
Steel--Structural	Lbs	16,500	4.45	73,600		
Steel--Reinforcing	Lbs	51,300	.50	25,700		
Concrete--Abutment	CY	100	88.94	9,100		
Concrete--Gate Sill	CY	200	53.36	10,900		
Cement	CWT	1,900	6.20	11,900		
Control System						
Tank, Pump & Motors	Job	1	L.S.	11,900		
Hydraulic System	Job	1	L.S.	5,900		

TABLE D-5. (Continued)

Description	Unit	Quantity	Unit Price	Amount	Subtotal	Total
Flood Control (cont'd)						
Electrical Control System	Job	1	L.S.	9,500		
Paint Gates	Job	1	L.S.	11,900		
					178,900	
Extend Existing Side Drain	Job	1	L.S.	6,100	6,100	
Subtotal					2,411,300	
Contingency (20%)					482,300	
Total Construction Costs					2,893,600	
Engineering & Design (10%)					289,400	
Supervision & Administration (10%)					289,400	
Total						$3,472,400
	SAY					$3,473,000
Clear South Side	L.S.	1	26,800	26,800		
Contingencies (15%)				4,000		
Subtotal					30,800	
Engineering & Design (0%)				--		
Supervision & Administration (15%)					4,600	
Total						$ 35,400
	SAY					$ 36,000
Phreatophyte Clearance	Acre	322	711.48	229,100		
Contingencies (5%)				11,500		
Subtotal					240,600	
Engineering & Design (2%)					4,800	
Supervision & Administration (10%)					24,100	
Total						$ 269,500
	SAY					$ 270,000

TABLE D-5. (Continued)

Description	Unit	Quantity	Unit Price	Amount	Subtotal	Total
Low Flow Channel	CY	115,555	1.78	205,700		
Contingency (10%)				20,600		
Subtotal					226,300	
Engineering & Design (2%)					4,500	
Supervision & Administration (10%)					23,100	
Total						$ 253,900
	SAY					$ 254,000
Environmental Mitigation						
Along North Levee						
Cottonwoods and Willows	5 Gal	800	50.00	40,000		
Downstream Meander Channel						
Cottonwoods and Willows	5 Gal	200	50.00	10,000		
Bermuda and Salt Grass						
Stolons	Job	1	L.S.	24,000		
Subtotal					74,000	
Contingency (10%)					7,500	
Engineer & Design (2%)					1,500	
Supervision & Administration (10%)					8,000	
Total						$ 85,000
Lands and Relocations						
Rights of Way*	Job	1	L.S.	3,301,000		
Relocations						
Utilities	Job	1	L.S.	7,000		
RR Bridge	Job	1	L.S.	2,154,000		
Total Lands & Relocations					5,462,000	5,462,000
Beautification						
North Levee	Job	1	L.S.	40,100		
Ponding Area	Job	1	L.S.	62,500		
Subtotal					102,600	
Contingency (20%)					20,500	

TABLE D-5 - Continued

Description	Unit	Quantity	Unit Price	Amount	Subtotal	Total
Flood Control (cont'd)						
Engineering & Design (10%)					12,300	
Supervision & Administration (10%)					12,300	
Total						$ 147,700
	SAY					$ 148,000
Total Flood Control Costs						$9,728,000
Recreation						
Bike Trail						
Shade Structure	ea	2	1,500	3,000		
Park Bench	ea	2	90	180		
Drinking Fountain	ea	2	420	840		
Subtotal					4,020	
Contingency (20%)					800	
Engineering & Design (10%)					480	
Supervision & Administration (10%)					480	
Total						$ 5,800
Picnic Area						
Shade Structure	ea	10	2,000	20,000		
Picnic Table	ea	10	300	3,000		
Trash Container and Pads	ea	13	175	2,280		
BBQ	ea	10	120	1,200		
Play Equipment	ea	1	600	600		
Slide	ea	1	350	350		
Swings	ea	1	350	350		
Turf	SF	5,000	.07	350		
Irrigation	SF	5,000	.50	1,750		
Trees	ea	50	50	2,500		
Rest Room	SF	300	75	22,500		

TABLE D-5. (Continued)

Description	Unit	Quantity	Unit Price	Amount	Subtotal	Total
Subtotal					55,000	
Contingency (17%)					9,400	
Engineering & Design (10%)					6,400	
Supervision & Administration (10%)					6,400	
Total						$ 77,200
Total Recreation Costs						$ 83,000
Total Project Costs						$9,811,000

*Rights-of-way consist only real estate interests which must be purchased.

TABLE D-6. Cost estimate—Little Colorado River
Holbrook, Arizona
Double-Levee Plan (tentatively selected plan)
(September 1979 prices)

Description	Unit	Quantity	Unit Price	Amount	Subtotal	Total
Flood Control						
North Levee						
Clearing (Levee const)	Acre	59	700	41,300		
Diversion & Water Control	Job	1	L.S.	29,700		
Clearing Water Course	Acre	83	700	58,100		
Toe Excavation	CY	131,900	1.19	157,000		
Borrow Excavation	CY	476,600	1.42	677,000		
Compacted Fill Levee	CY	418,300	.42	176,000		
Compacted Back Fill Toe	CY	98,900	.53	52,400		
Facing Stone	CY	58,500	11.86	694,000		
Bedding Stone	CY	23,400	12.45	291,000		
Cement	CWT	7,300	6.20	45,300		
Grout	CY	980	35.57	34,900		
A.C. Pavement (Service Rd)	Ton	2,500	21.34	53,400		
					$2,310,000	
Remove Concrete	CY	180	47.43	8,600		
Miter Gate (Hwy 260)						
Steel - Structural	Lbs	16,500	4.45	73,400		
Steel - Reinforcing	Lbs	51,300	.50	25,700		
Concrete - Abutment	CY	100	88.94	8,900		
Concrete - Gate Sill	CY	200	53.36	10,700		
Cement	CWT	1,900	6.20	11,800		
Control System						
Tank, Pump & Motors	Job	1	L.S.	11,900		
Hydraulic System	Job	1	L.S.	6,000		
Electrical Control System	Job	1	L.S.	9,500		
Paint Gates	Job	1	L.S.	11,900		
					178,400	

TABLE D-6. (Continued)

Description	Unit	Quantity	Unit Price	Amount	Subtotal	Total
Extend Existing Side Drain	Job	1	L.S.	6,100		
					6,100	
Subtotal					2,494,000	
Contingency (20%)					499,000	
Total Construction Costs					2,994,000	
Engineering & Design (10%)					300,000	
Supervision & Administration (10%)					300,000	
Total						$3,594,000
South Levee						
Clearing (Levee Const)	Acre	11	700	7,700		
Excavation - Toe	CY	27,200	1.19	32,400		
Excavation - Borrow	CY	208,600	1.42	296,000		
Compacted Fill - Levee	CY	181,400	.42	76,200		
Compacted Fill - Backfill Toe	CY	19,100	.53	10,200		
Stone - Facing	CY	18,800	11.86	223,000		
Stone - Bedding	CY	6,300	12.45	78,500		
Approach Fill	CY	8,300	1.78	14,800		
Base Course	CY	400	19.57	7,900		
A.C. Pavement	Ton	900	21.34	19,200		
Guard Rail	LF	1,800	19.57	35,300		
					801,000	
Side Drain Structure	Job	1	L.S.	7,000		
					7,000	
Remove Concrete	CY	180	47.43	8,600		
Miter Gate						
Steel - Structural	Lbs	16,700	4.45	74,300		

TABLE D-6. (Continued)

Description	Unit	Quantity	Unit Price	Amount	Subtotal	Total
Flood Control (cont'd)						
Steel - Reinforcing	Lbs	59,700	.50	29,900		
Concrete - Abutment	CY	200	88.94	17,800		
Concrete - Gate Sill	CY	200	53.36	10,700		
Cement	CWT	2,200	6.20	13,700		
Control System						
Tank, Pump and Motors	Job	1	L.S.	11,900		
Hydraulic System	Job	1	L.S.	5,900		
Electrical Control System	Job	1	L.S.	9,500		
Paint Gates	Job	1	L.S.	11,900		
Subtotal					194,000	
South Side Drain						
Bridge South of Levee						
Concrete - Superstructure	CY	100	1.91	19,100		
Concrete - Abutment	CY	10	54.55	550		
Concrete - Footing	CY	40	43	1,700		
Bridge Railing	LF	120	17.79	2,200		
Detour	Job	1	L.S.	13,100		
A.C. Pavement	Ton	30	21.34	640		
Base Course	CY	40	19.57	780		
Guard Rail	LF	200	19.57	3,900		
Steel - Reinforcing	Lbs	29,400	.50	14,700		
Cement	CWT	900	6.20	5,600		
Excavation - Footing	CY	90	1.96	180		
Backfill - Footing	CY	50	.53	30		
Approach Fill	CY	300	1.78	530		
Mob and Demob	Job	1	L.S.	8,300		
Subtotal					71,300	

TABLE D-6. (Continued)

Description	Unit	Quantity	Unit Price	Amount	Subtotal	Total
Side Drain Channel and Structure						
Clearing - Site	Acre	3	700	2,100		
Excavation - Channel	CY	5,200	1.42	7,400		
Excavation - Toe	CY	1,300	1.19	1,600		
Compacted Backfill - Toe	CY	1,200	.53	640		
Stone - Facing	CY	1,600	11.86	19,000		
Bedding	CY	800	12.45	10,000		
Structure (5-8' W x 7'H x 70'L)	Job	1	L.S.	34,100		
Cement	CWT	2,100	6.20	13,000		
Steel - Reinforcing	Lbs	37,800	.50	19,000		
Flap Gates (5-8' x 7')	ea	5	16,245	81,000		
Rip-Rap	CY	30	1.86	360		
Toe Excavation	CY	100	1.19	120		
Toe Backfill	CY	70	.53	40		
Subtotal					188,000	
Structure (3-6' x 5'H x 70'L)	Job	1	L.S.	16,000		
Cement	CWT	1,090	6.20	6,300		
Steel - Reinforcing	Lbs	18,000	.50	9,000		
Flap Gates (3-6' x 5')	ea	3	8,063	24,000		
Rip-Rap	CY	75	11.86	890		
Excavation - Toe	CY	242	1.19	290		
Backfill - Toe	CY	30	.53	20		
Grout	CY	10	35.57	360		
Subtotal					57,400	
Contingency (20%)					264,000	
Total Construction Costs					1,574,000	
Engineering & Design (10%)					157,400	
Supervision & Administration (10%)					157,400	
Total (South Side)						$1,888,800
	SAY					$1,889,000

TABLE D-6. (Continued)

Description	Unit	Quantity	Unit Price	Amount	Subtotal	Total
Flood Control (cont'd)						
Phreatophyte Clearance	Acre	322	711.48	229,100		
Contingency (5%)				11,500		
Subtotal					240,000	
Engineering & Design (2%)					4,800	
Supervision & Administration (10%)					24,100	
Total						$ 269,500
	SAY					$ 270,000
Low Flow Channel	CY	115,555	1.78	205,700		
Contingency (10%)				20,600		
Subtotal					226,300	
Engineering & Design (2%)					4,600	
Supervision & Administration (10%)					22,700	
Total						$ 253,600
	SAY					$ 254,000
Environmental Mitigation						
Along North Levee						
Cottonwoods and Willows	5 Gal	800	50.00	40,000		
Downstream Meander Channel						
Cottonwoods and Willows	5 Gal	200	50.00	10,000		
Bermuda and Salt Grass Stolons	Job	1	L.S.	24,000		
Subtotal					74,000	
Contingency (10%)					7,400	
Engineer & Design (2%)					1,700	
Supervision & Administration (10%)					8,200	
Total						$ 91,300
	SAY					$ 91,000

TABLE D-6. (Continued)

Description	Unit	Quantity	Unit Price	Amount	Subtotal	Total
Lands and Relocations						
Rights of Way	Job	1	L.S.	1,129,000		
Relocations						
Utilities	Job	1	L.S.	7,000		
RR Bridge	Job	1	L.S.	2,153,000		
Total Lands & Relocations					3,289,000	$3,289,000
Beautification						
North Levee	Job	1	L.S.	40,100		
South Levee	Job	1	L.S.	11,300		
Ponding Area	Job	1	L.S.	62,500		
Subtotal					113,900	
Contingency (20%)					22,800	
Engineering & Design (10%)					13,700	
Supervision & Administration (10%)					13,700	
Total						$ 164,100
	SAY					$ 164,000
Total Flood Control Costs						$9,551,000
Recreation						
Bike Trail						
Shade Structure	ea	2	1,500	3,000		
Park Bench	ea	2	90	180		
Drinking Fountain	ea	2	420	840		
Subtotal					4,020	
Contingency (20%)					800	
Engineering & Design (10%)					480	
Supervision & Administration (10%)					480	
Total						$ 5,780
	SAY					$ 5,800

TABLE D-6. (Continued)

Description	Unit	Quantity	Unit Price	Amount	Subtotal	Total
Picnic Area						
Shade Structure	ea	10	2,000	20,000		
Picnic Table	ea	10	300	3,000		
Trash Container and Pads	ea	13	175	2,300		
BBQ	ea	10	120	1,200		
Play Equipment	ea	1	600	600		
Slide	ea	1	350	350		
Swings	ea	1	350	350		
Turf	SF	5,000	.07	350		
Irrigation	SF	5,000	.35	1,800		
Trees	ea	50	50	2,500		
Rest Room	SF	300	75	22,500		
Subtotal					55,000	
Contingency (17%)					9,400	
Engineering & Design (10%)					6,500	
Supervision & Administration (10%)					6,500	
Total						$ 77,400
Total Recreation Costs						$ 83,200
	SAY					$ 83,200
Total Project Costs						$9,634,000

TABLE D-7. Cost of floodproofing a single family residence. (September 1979 prices)

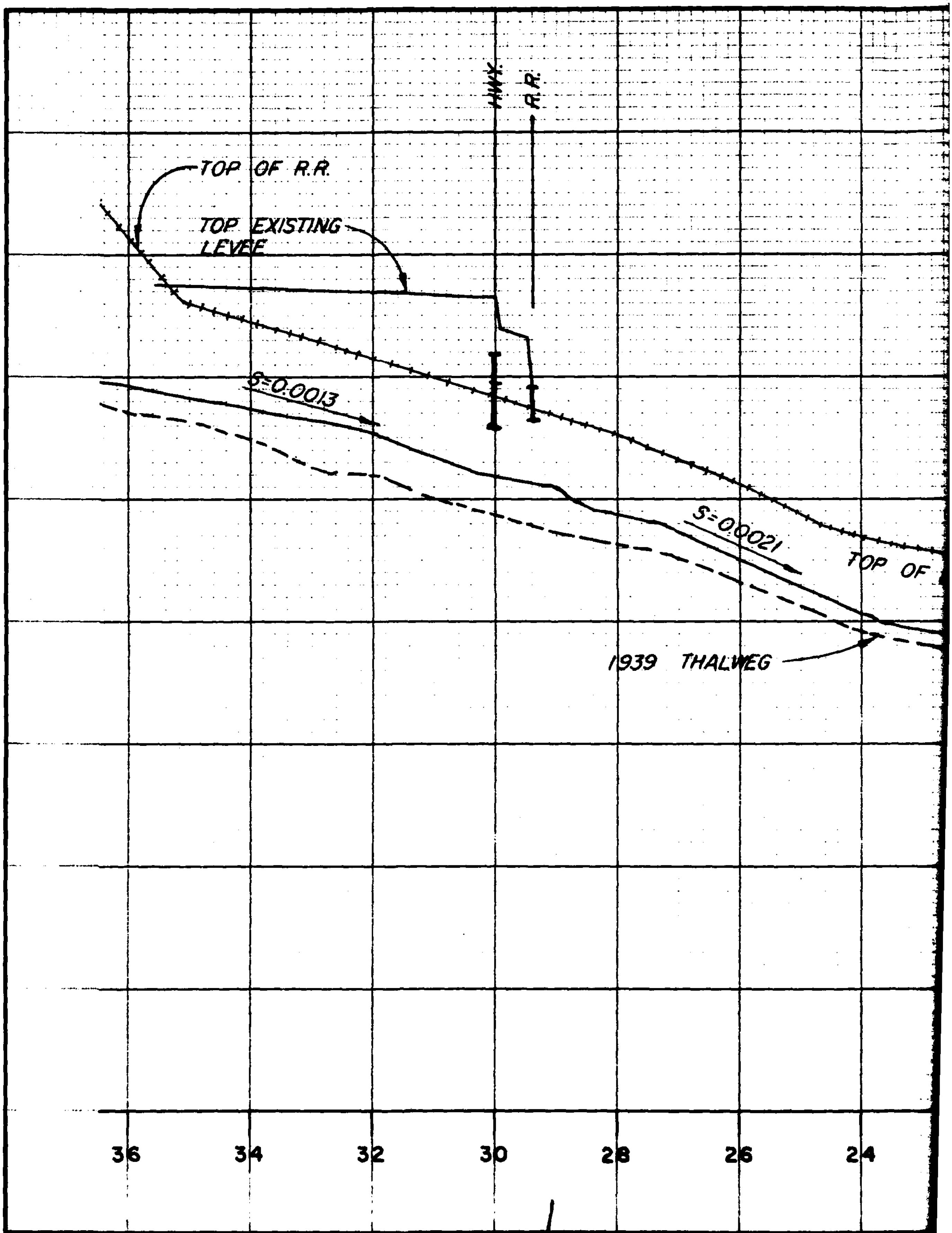
Item	Cost
Architectural fee	$ 1,800
Professional mover	5,300
Exterior treatment (stairs, walkway, etc.)	1,400
Foundation	2,100
Duct work	1,800
Minor structural repairs	1,100
Modifications to heating and cooling system	600
Esthetic treatment	2,400
Contingencies (17%)	2,900
Total	$19,400

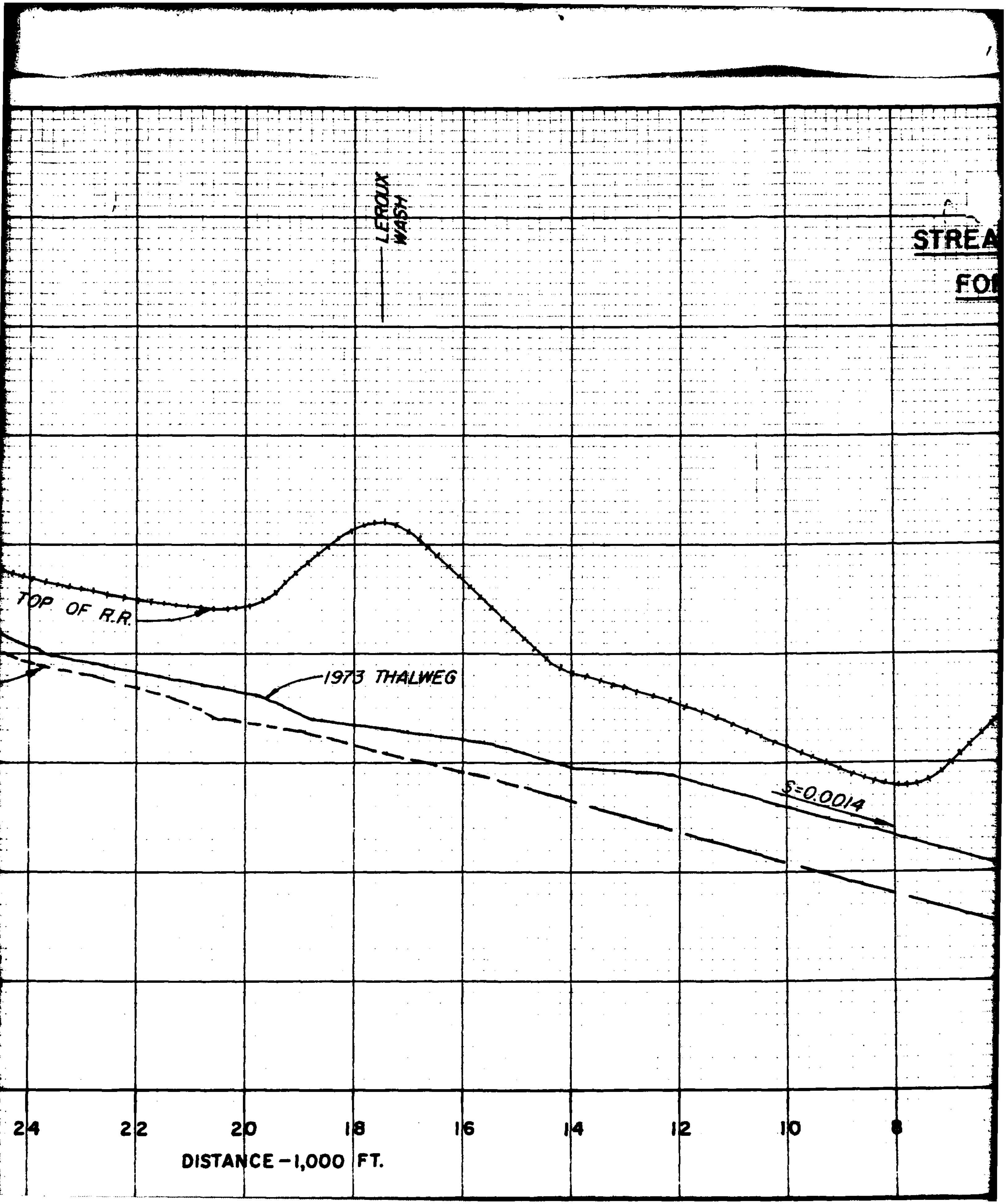
TABLE D-8. Cost estimate - floodproofing plan*
(September 1979 prices)

Building type	Number of buildings	Unit Cost	Cost
Single family residences flood depths greater than 2 feet	509	$19,400	$ 9,875,000
Single family residences flood depths less than 2 feet	71	13,300	944,000
Commercial			
Auto repair and sales	13	19,300	251,000
Strip	71	19,300	1,370,000
Two-story	4	19,300	77,000
Motels	18	89,500	1,611,000
Restaurants	10	19,300	193,000
Gas stations	14	19,300	270,000
Public			
Offices	15	30,200	453,000
Schools**	34	37,500	1,275,000
Churches	9	30,200	272,000
Industrial			
Warehouses	9	89,500	806,000
Manufacturing	14	89,500	1,253,000
Total	791		$18,650,000

* Mobile homes not included. North side of river only. A few abandoned houses were eliminated.

** Differs from economic appendix. This figure shows actual number of buildings compared to number of schools shown in economics.


HWY.
R.R.
TOP OF R.R.
TOP EXISTING LEVEE
S=0.0013
S=0.0021
TOP OF
1939 THALWEG
36
34
32
30
28
26
24



STREA
FO
LEROUX WASH
TOP OF R.R.
1973 THALWEG
S=0.0014
24
22
20
18
16
14
12
10
8
DISTANCE - 1,000 FT.

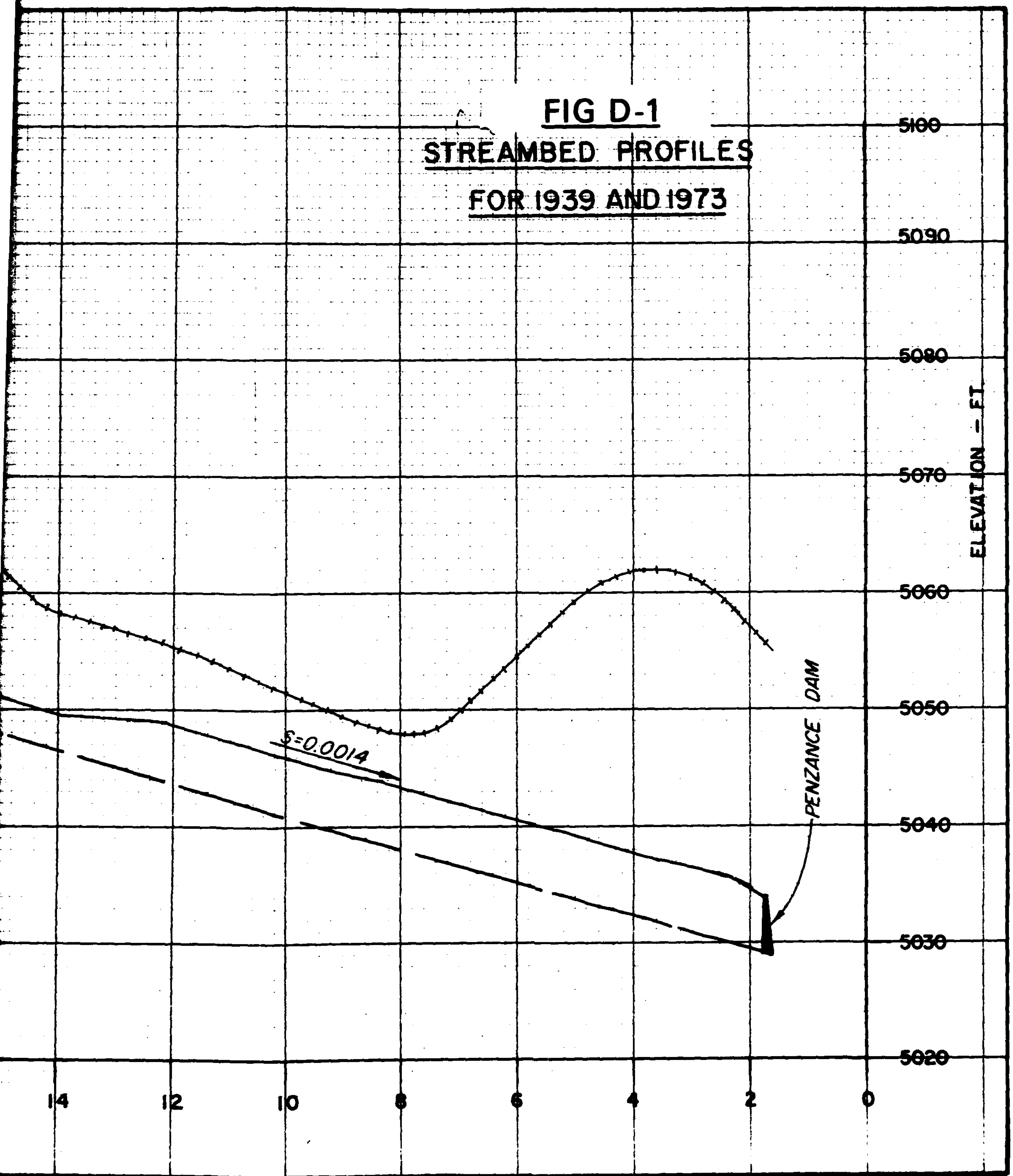
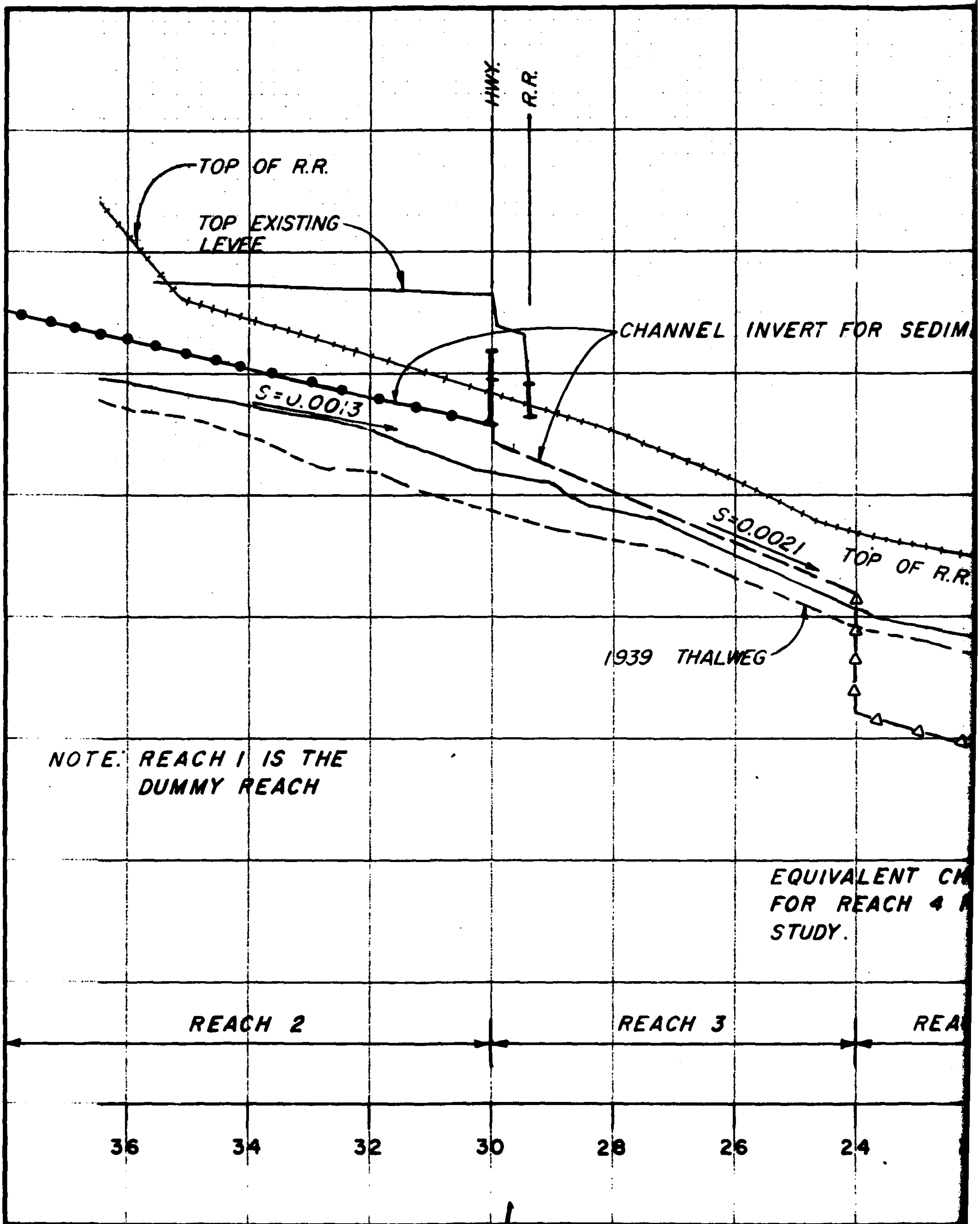
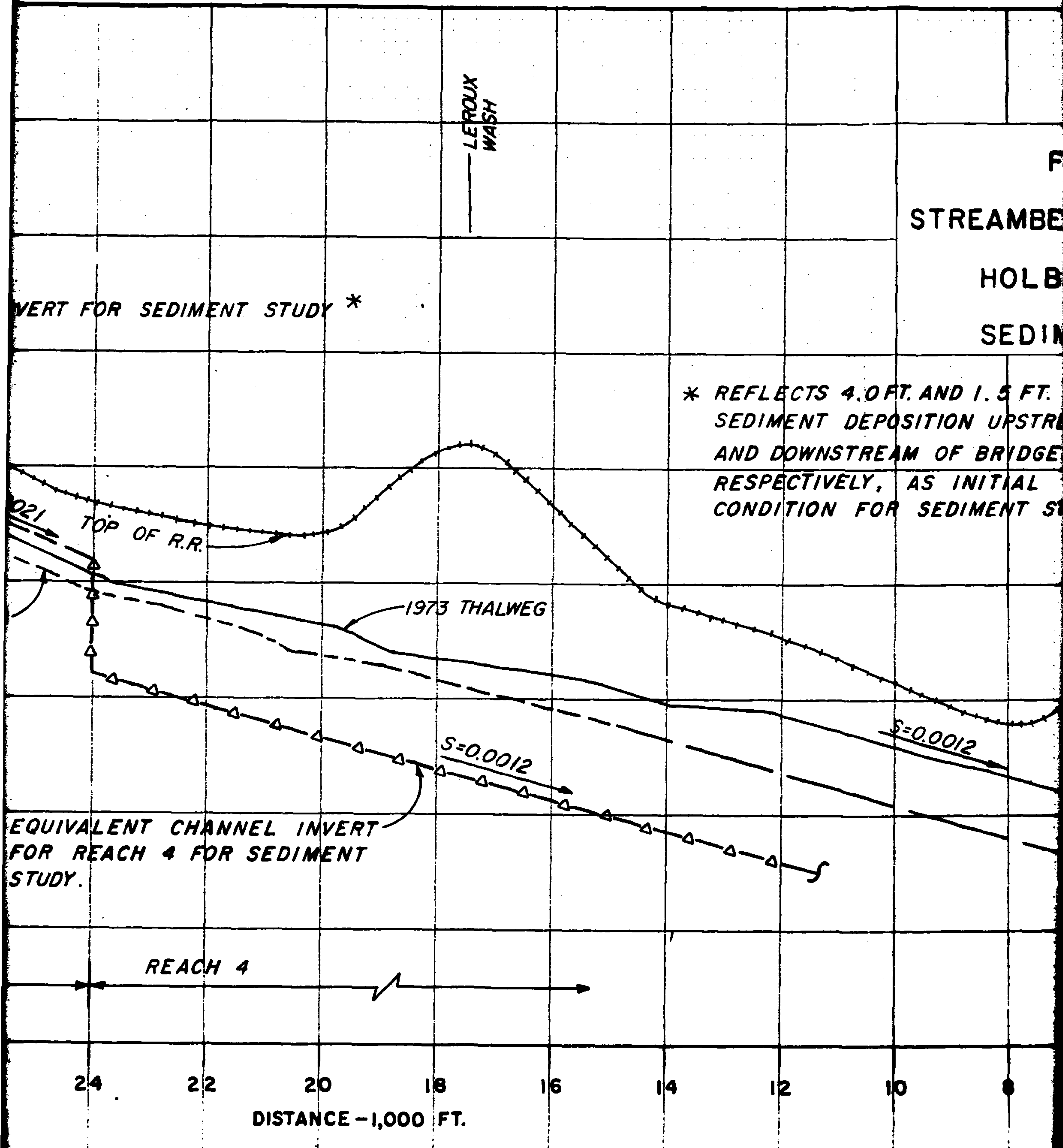


FIG D-1
STREAMBED PROFILES
FOR 1939 AND 1973


HWY.
R.R.
TOP OF R.R.
TOP EXISTING LEVEE
CHANNEL INVERT FOR SEDIM
S=0.0013
S=0.0021
TOP OF R.R.
1939 THALWEG
NOTE: REACH 1 IS THE DUMMY REACH
EQUIVALENT CH
FOR REACH 4
STUDY.
REACH 2
REACH 3
REA
36
34
32
30
28
26
24


LEROUX WASH
F
STREAMBE
HOLB
SEDI
VERT FOR SEDIMENT STUDY *
* REFLECTS 4.0 FT. AND 1.5 FT.
SEDIMENT DEPOSITION UPSTR
AND DOWNSTREAM OF BRIDGE
RESPECTIVELY, AS INITIAL
CONDITION FOR SEDIMENT S
021
TOP OF R.R.
1973 THALWEG
S=0.0012
S=0.0012
EQUIVALENT CHANNEL INVERT
FOR REACH 4 FOR SEDIMENT
STUDY.
REACH 4
24
22
20
18
16
14
12
10
8
DISTANCE-1,000 FT.

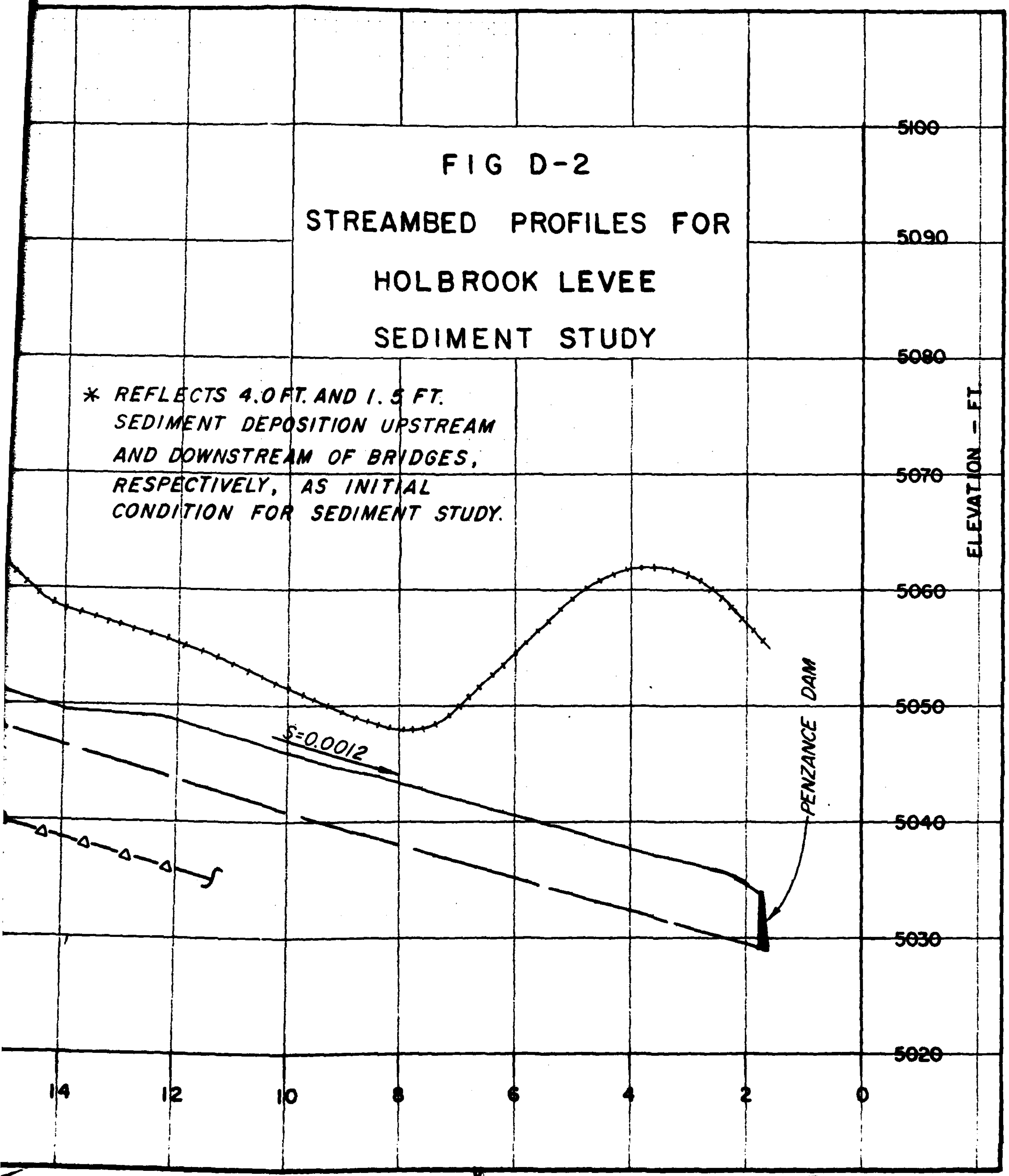
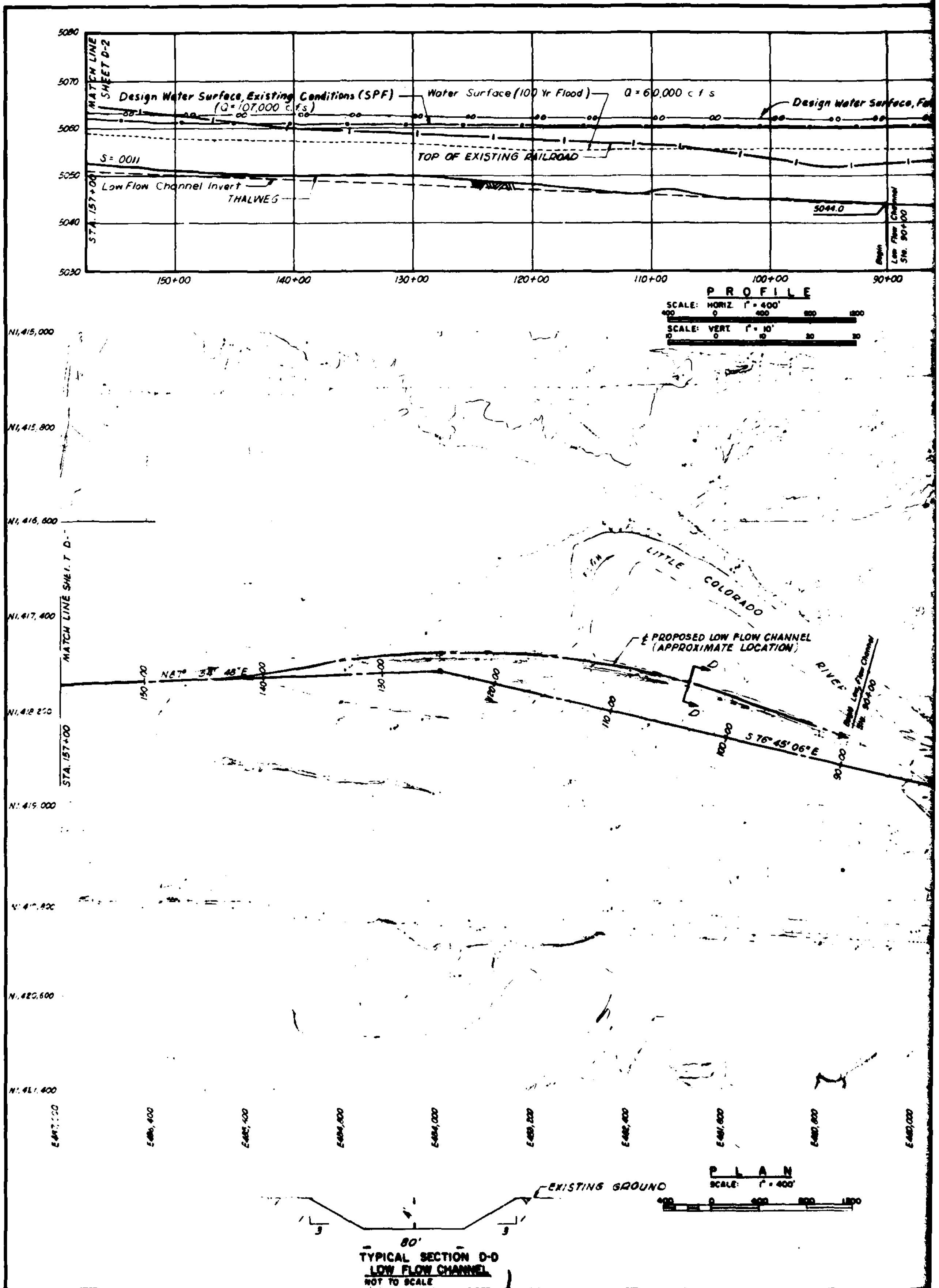
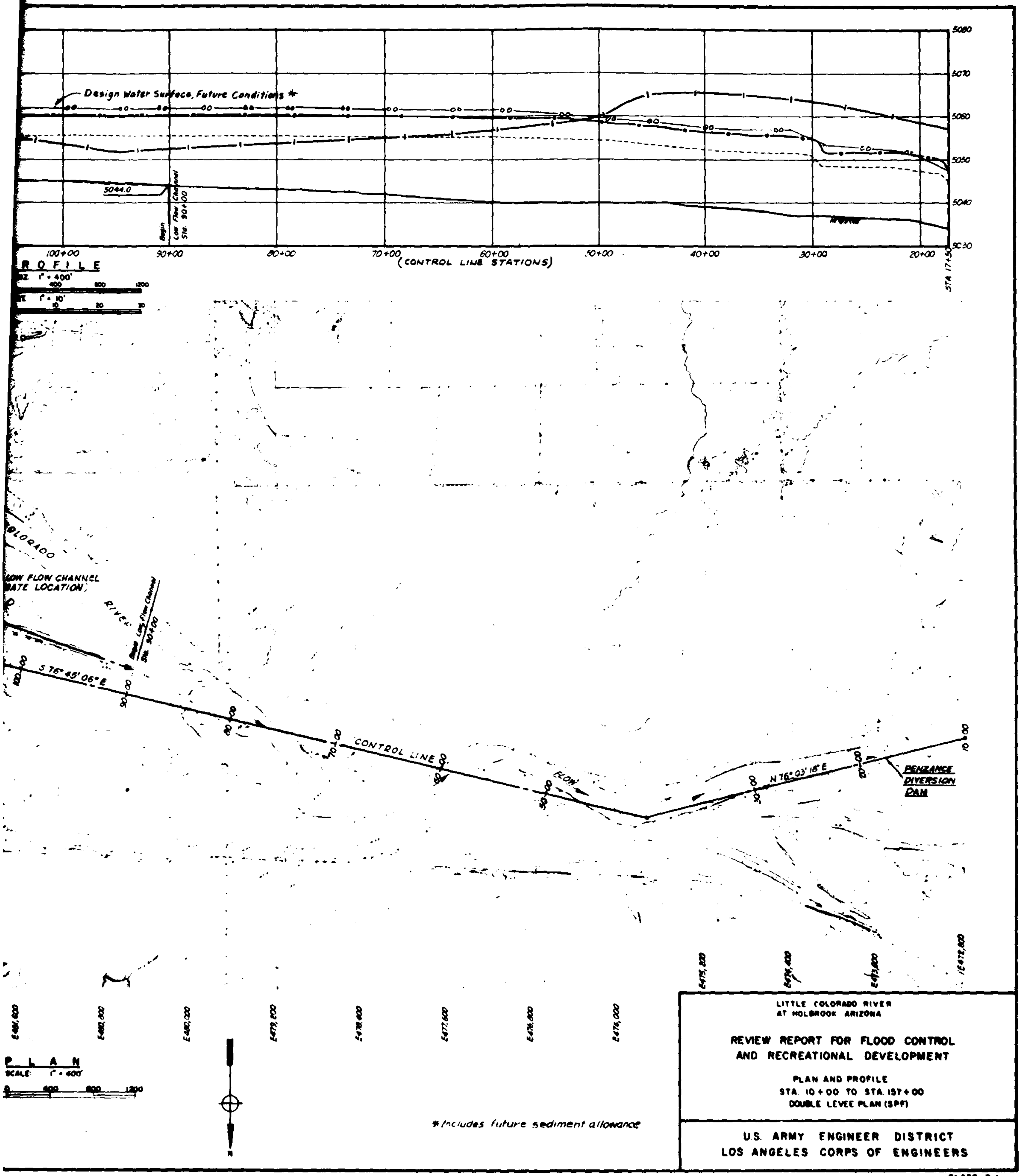


FIG D-2
STREAMBED PROFILES FOR
HOLBROOK LEVEE
SEDIMENT STUDY
* REFLECTS 4.0 FT. AND 1.5 FT. SEDIMENT DEPOSITION UPSTREAM AND DOWNSTREAM OF BRIDGES, RESPECTIVELY, AS INITIAL CONDITION FOR SEDIMENT STUDY.
S=0.0012
PENZANCE DAM
ELEVATION - FT.
5100
5090
5080
5070
5060
5050
5040
5030
5020
14
12
10
8
6
4
2
0



MATCH LINE SHEET D-2
Design Water Surface, Existing Conditions (SPF)
(Q = 107,000 c.f.s)
Water Surface (100 Yr Flood)
Q = 60,000 c f s
Design Water Surface
TOP OF EXISTING RAILROAD
S = .0011
Low Flow Channel Invert
THALWEG
STA. 157+00
5044.0
Begin Low Flow Channel Sta. 90+00
5080
5070
5060
5050
5040
5030
150+00
140+00
130+00
120+00
110+00
100+00
90+00
PROFILE
SCALE: HORIZ. 1" = 400'
SCALE: VERT. 1" = 10'
MATCH LINE SHEET D-
STA. 157+00
N 87° 34' 48" E
S 76° 45' 06" E
LITTLE COLORADO RIVER
℄ PROPOSED LOW FLOW CHANNEL (APPROXIMATE LOCATION)
Begin Low Flow Channel Sta. 90+00
D
D
PLAN
SCALE: 1" = 400'
EXISTING GROUND
80'
3
3
TYPICAL SECTION D-D
LOW FLOW CHANNEL
NOT TO SCALE



LITTLE COLORADO RIVER
AT HOLBROOK ARIZONA

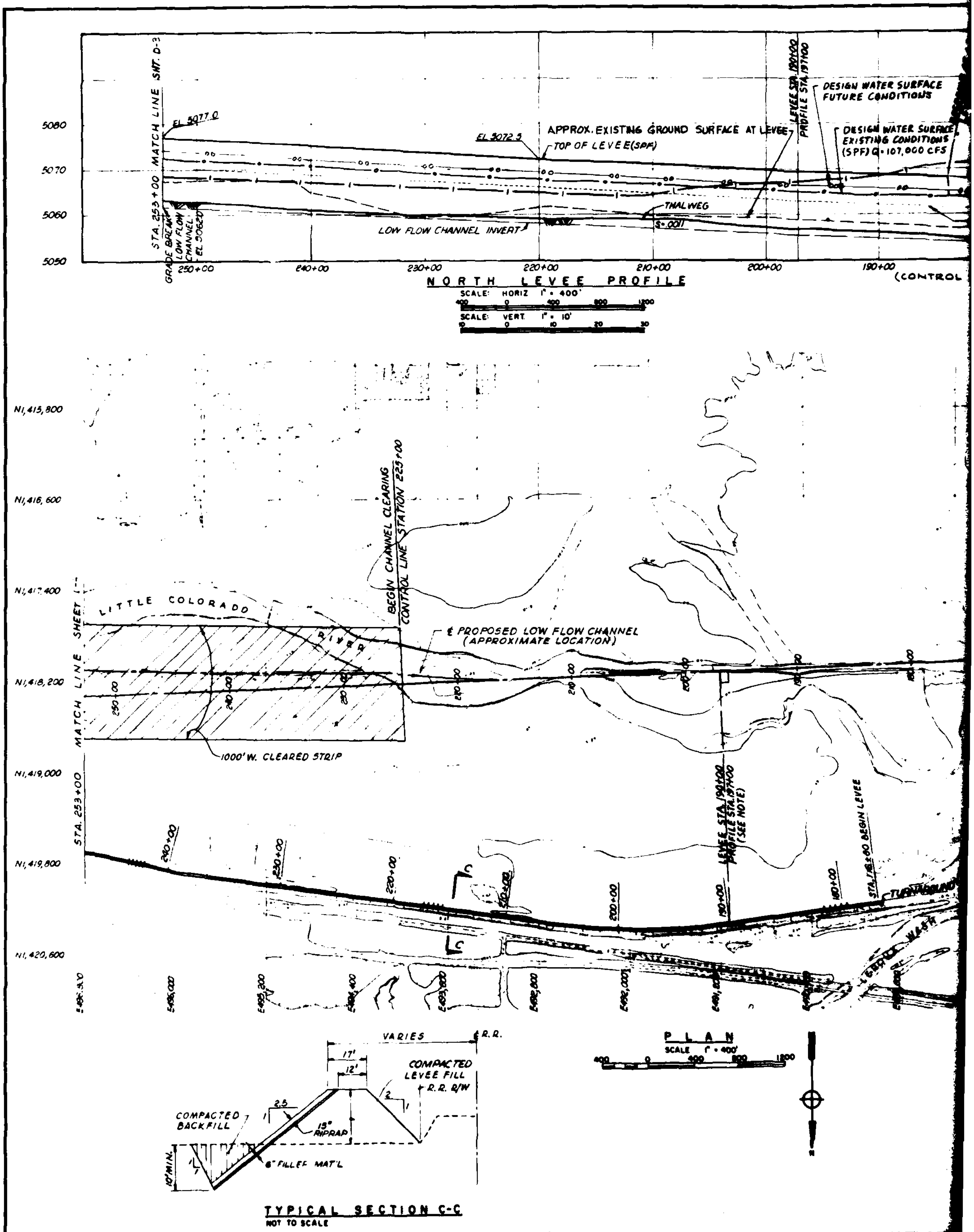
REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

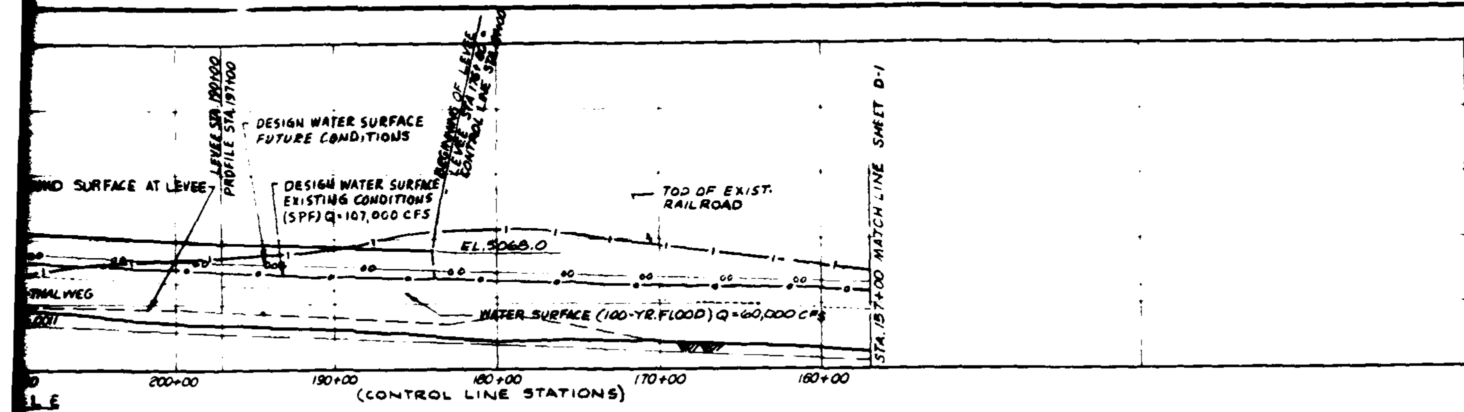
PLAN AND PROFILE
STA. 10+00 TO STA. 157+00
DOUBLE LEVEE PLAN (SPF)

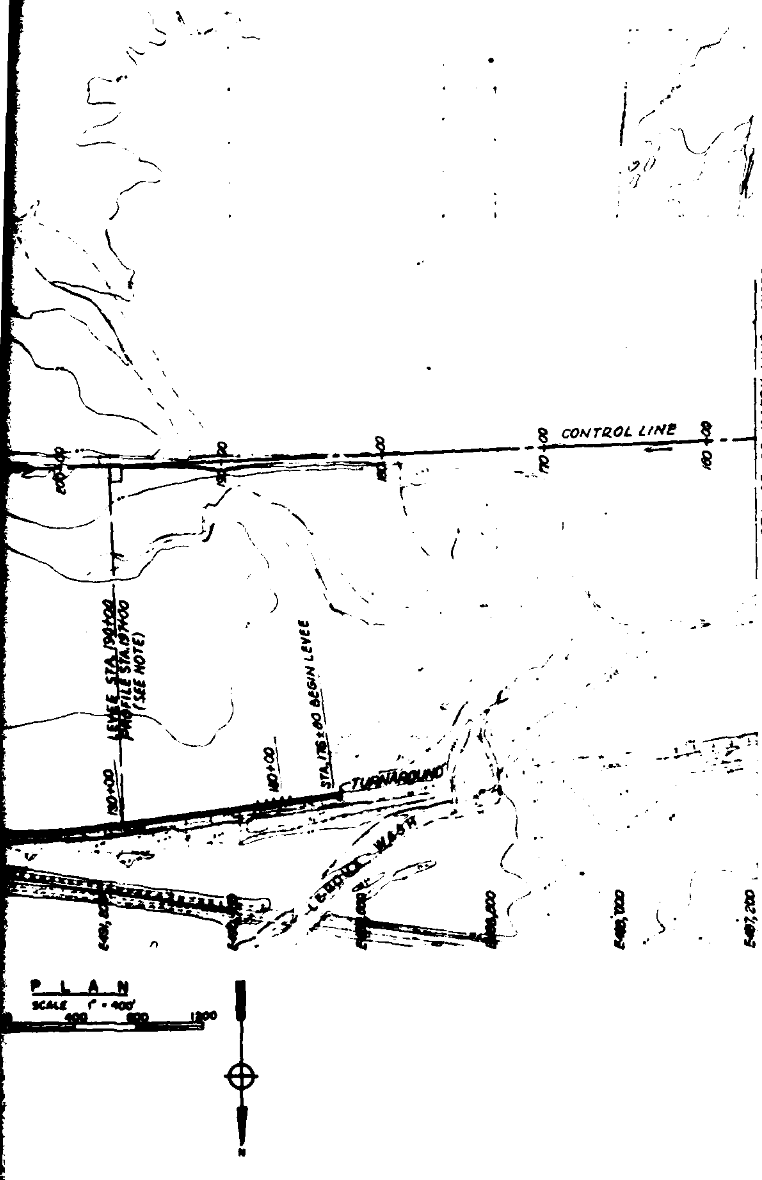
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES CORPS OF ENGINEERS

* Includes future sediment allowance

PLATE B-1


NORTH LEVEE PROFILE
SCALE: HORIZ 1" = 400'
SCALE: VERT. 1" = 10'
MATCH LINE SHT. D-3
STA. 253+00 GRADE BREAK LOW FLOW CHANNEL EL 5062.0
EL 5077.0
EL 5072.5
APPROX. EXISTING GROUND SURFACE AT LEVEE
TOP OF LEVEE (SPF)
LEVEE STA. 190+00 PROFILE STA. 197+00
DESIGN WATER SURFACE FUTURE CONDITIONS
DESIGN WATER SURFACE EXISTING CONDITIONS (SPF) Q=107,000 CFS
THALWEG
S=.0011
LOW FLOW CHANNEL INVERT
5080
5070
5060
5050
250+00
240+00
230+00
220+00
210+00
200+00
190+00
(CONTROL
N1,415,800
N1,416,600
N1,417,400
N1,418,200
N1,419,000
N1,419,800
N1,420,600
LITTLE COLORADO RIVER
MATCH LINE SHEET
BEGIN CHANNEL CLEARING CONTROL LINE STATION 225+00
℄ PROPOSED LOW FLOW CHANNEL (APPROXIMATE LOCATION)
1000' W. CLEARED STRIP
STA. 253+00
LEVEE STA. 190+00 PROFILE STA. 197+00 (SEE NOTE)
STA. 178+00 BEGIN LEVEE
TURNAROUND
PLAN
SCALE 1" = 400'
VARIES
℄ R.R.
17'
12'
COMPACTED LEVEE FILL
R.R. R/W
COMPACTED BACKFILL
2.5
2
13" RIPRAP
6" FILLER MAT'L
10' MIN.
TYPICAL SECTION C-C
NOT TO SCALE

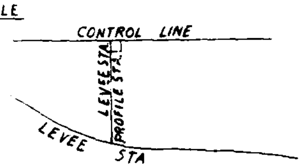




NOTES

PROFILE STATIONS BASED ON CONTROL LINE STATIONS
WATER SURFACE PROFILES ARE ALONG CONTROL LINE.
ALL OTHER PROFILES ARE PROJECTED PERPENDICULAR TO CONTROL LINE.

EXAMPLE



*Includes future sediment allowance

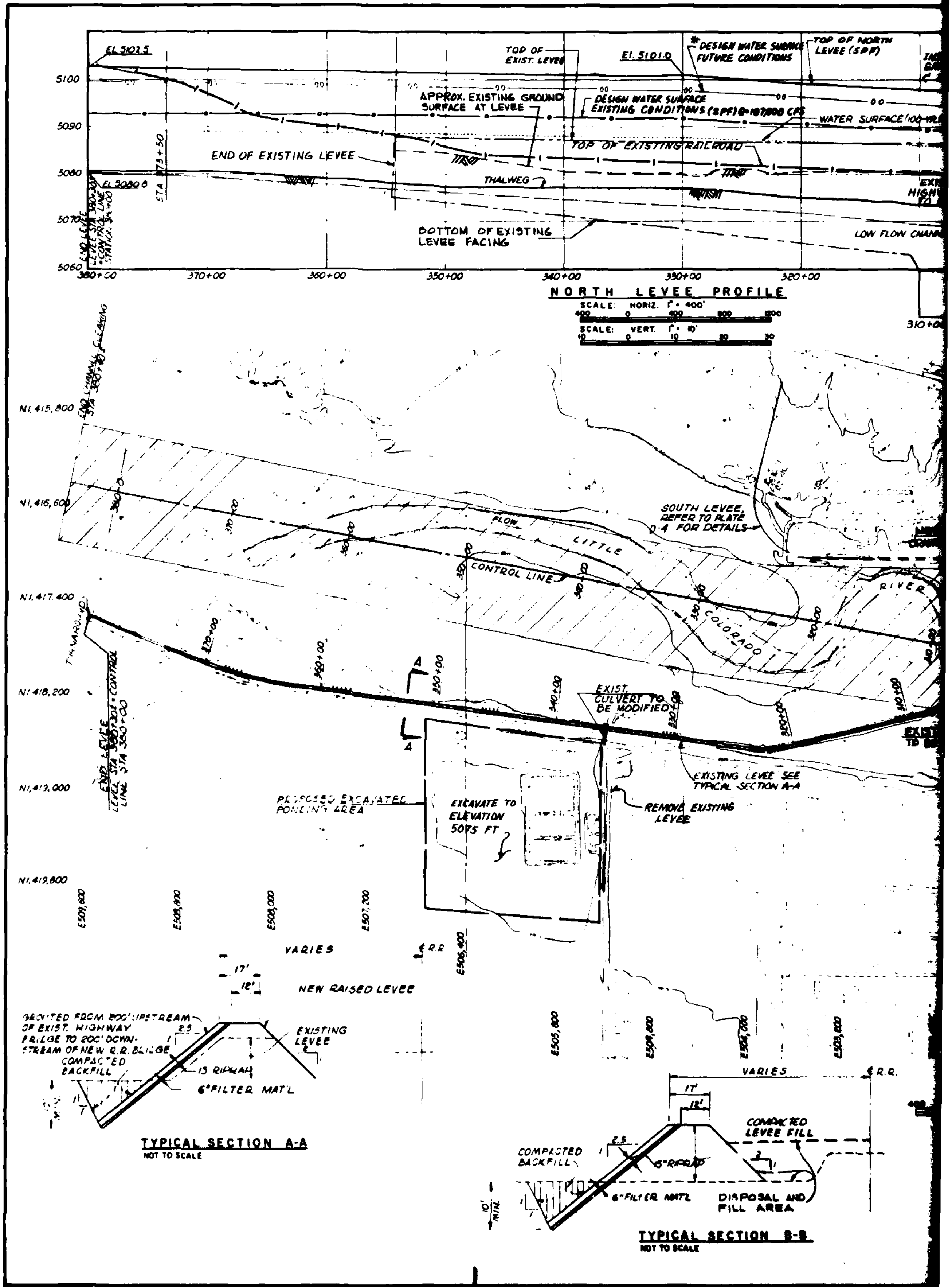
LITTLE COLORADO RIVER
AT HOLBROOK ARIZONA

REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

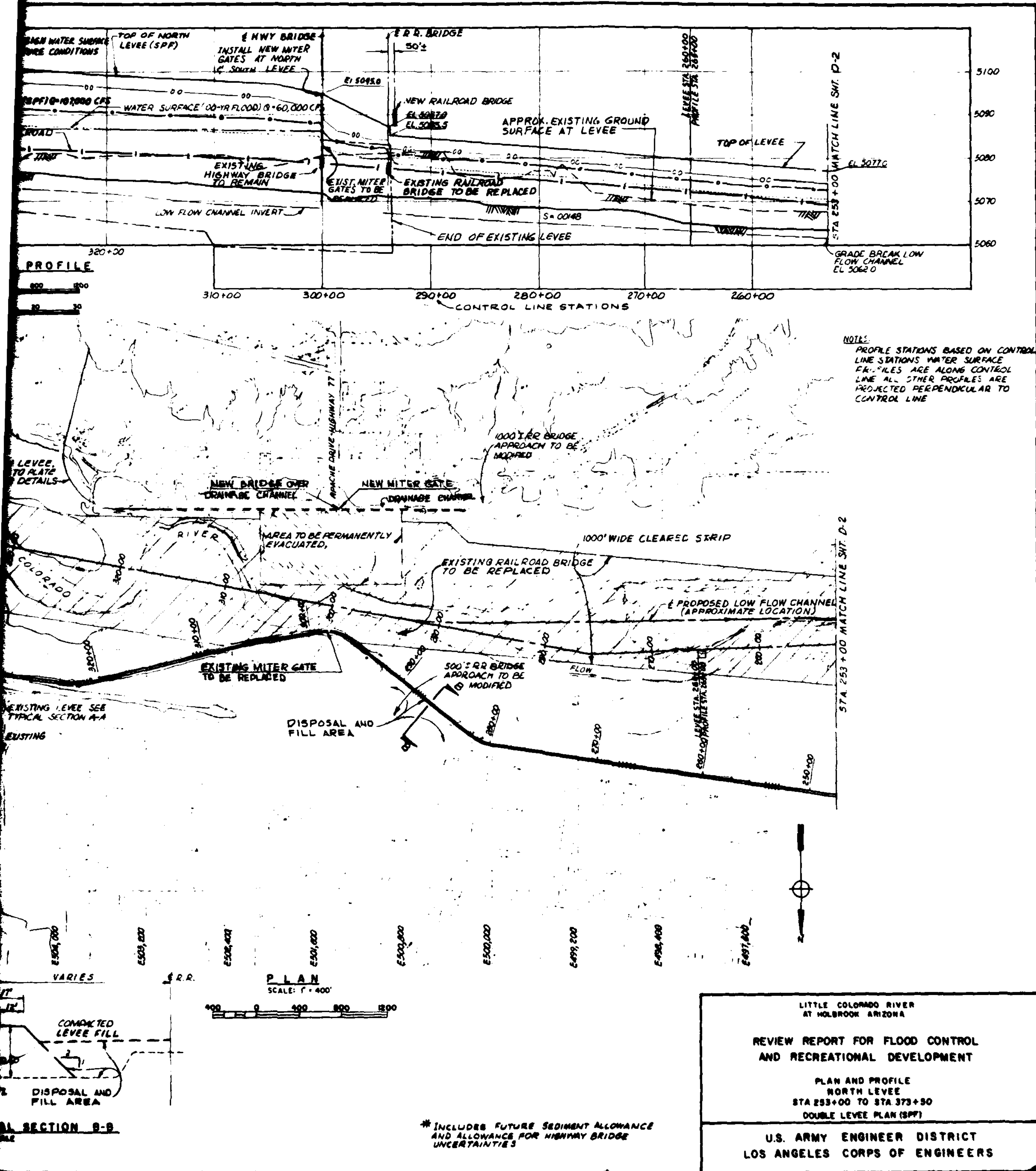
PLAN AND PROFILE
STA. 157+00 TO STA. 253+00
DOUBLE LEVEE PLAN (SPF)

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES CORPS OF ENGINEERS

PLATE D-2



EL 5102.5
TOP OF EXIST. LEVEE
EL. 5101.0
*DESIGN WATER SURFACE FUTURE CONDITIONS
TOP OF NORTH LEVEE (SPF)
APPROX. EXISTING GROUND SURFACE AT LEVEE
DESIGN WATER SURFACE EXISTING CONDITIONS (SPF)
WATER SURFACE
TOP OF EXISTING RAILROAD
END OF EXISTING LEVEE
THALWEG
EL 5080.8
STA 373+50
BOTTOM OF EXISTING LEVEE FACING
LOW FLOW CHANNEL
5100
5090
5080
5070
5060
380+00
370+00
360+00
350+00
340+00
330+00
320+00
310+00
NORTH LEVEE PROFILE
SCALE: HORIZ. 1" = 400'
SCALE: VERT. 1" = 10'
N1,415,800
N1,416,600
N1,417,400
N1,418,200
N1,419,000
N1,419,800
SOUTH LEVEE, REFER TO PLATE 4 FOR DETAILS
FLOW
LITTLE
CONTROL LINE
RIVER
COLORADO
EXIST. CULVERT TO BE MODIFIED
EXISTING LEVEE SEE TYPICAL SECTION A-A
PROPOSED EXCAVATED PONDING AREA
EXCAVATE TO ELEVATION 5075 FT
REMOVE EXISTING LEVEE
E509,600
E508,800
E508,000
E507,200
E506,400
E505,600
E504,800
E504,000
E503,200
VARIES
℄ R.R.
17'
12'
NEW RAISED LEVEE
EXISTING LEVEE
COMPACTED BACKFILL
6" FILTER MAT'L
TYPICAL SECTION A-A
NOT TO SCALE
COMPACTED LEVEE FILL
COMPACTED BACKFILL
DISPOSAL AND FILL AREA
10' MIN.
TYPICAL SECTION B-B
NOT TO SCALE



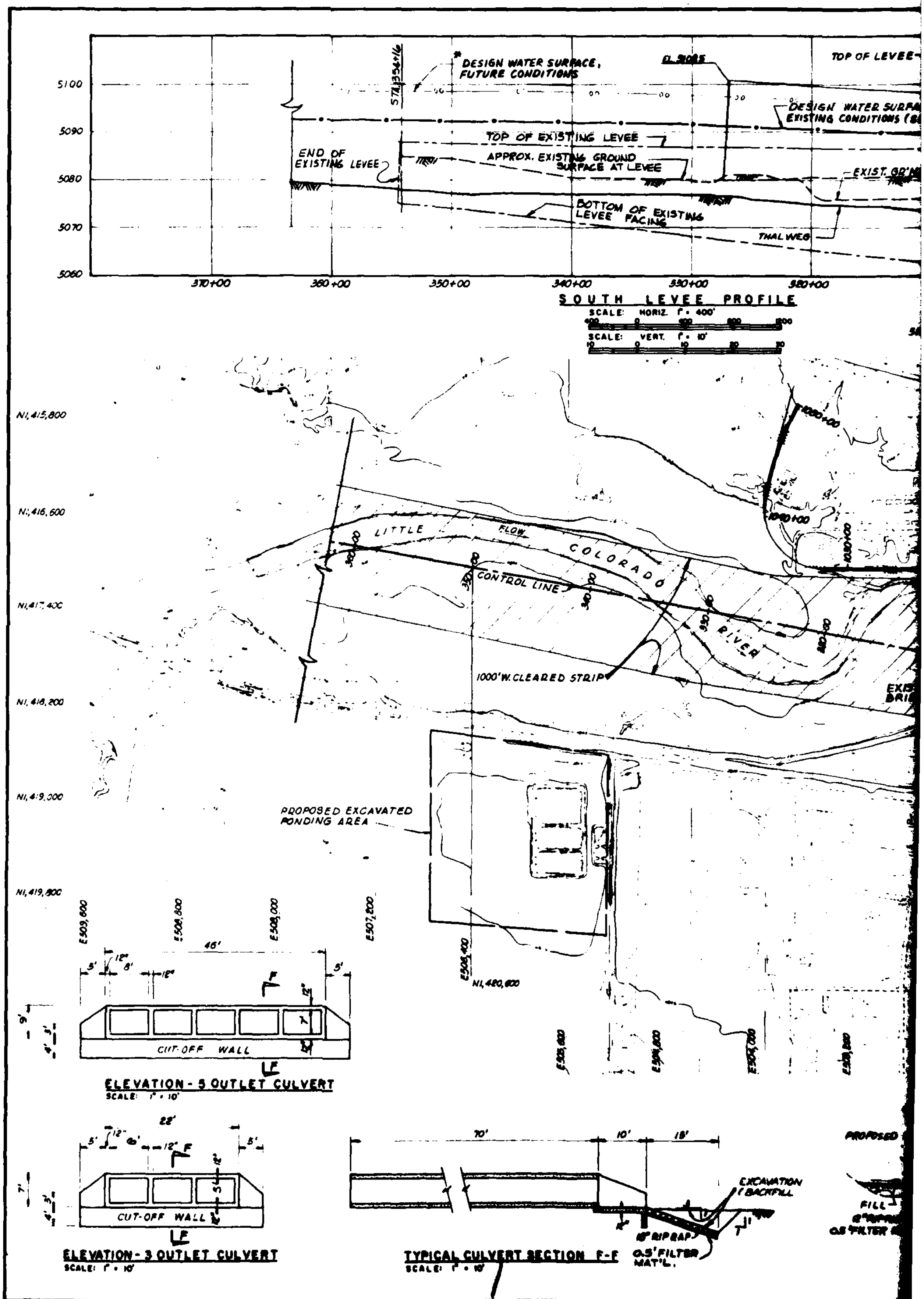
LITTLE COLORADO RIVER
AT HOLBROOK ARIZONA

REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

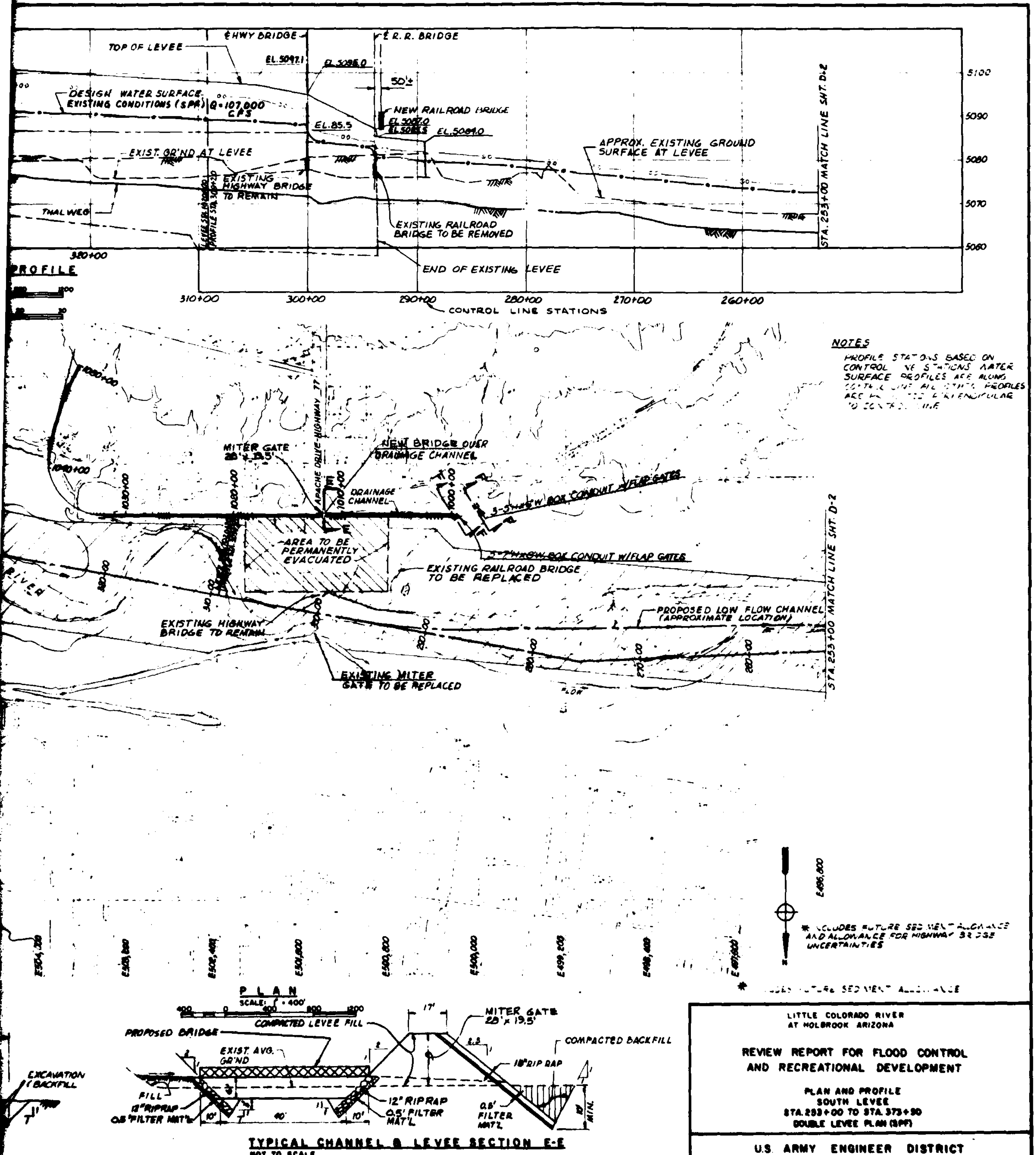
PLAN AND PROFILE
NORTH LEVEE
STA 253+00 TO STA 373+50
DOUBLE LEVEE PLAN (SPF)

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES CORPS OF ENGINEERS

PLATE D-3



DESIGN WATER SURFACE, FUTURE CONDITIONS
TOP OF LEVEE
DESIGN WATER SURFACE EXISTING CONDITIONS
TOP OF EXISTING LEVEE
END OF EXISTING LEVEE
APPROX. EXISTING GROUND SURFACE AT LEVEE
BOTTOM OF EXISTING LEVEE FACING
THALWEG
5100
5090
5080
5070
5060
370+00
360+00
350+00
340+00
330+00
320+00
SOUTH LEVEE PROFILE
SCALE: HORIZ. 1" = 400'
SCALE: VERT. 1" = 10'
N1,415,800
N1,416,600
N1,417,400
N1,418,200
N1,419,000
N1,419,800
N1,420,600
LITTLE COLORADO RIVER
FLOW
CONTROL LINE
1000'W. CLEARED STRIP
PROPOSED EXCAVATED PONDING AREA
E509,600
E508,800
E508,000
E507,200
E506,400
ELEVATION - 5 OUTLET CULVERT
SCALE: 1" = 10'
CUT-OFF WALL
ELEVATION - 3 OUTLET CULVERT
SCALE: 1" = 10'
TYPICAL CULVERT SECTION F-F
SCALE: 1" = 10'
EXCAVATION & BACKFILL
18" RIPRAP
0.5' FILTER MAT'L.



LITTLE COLORADO RIVER
AT HOLBROOK ARIZONA

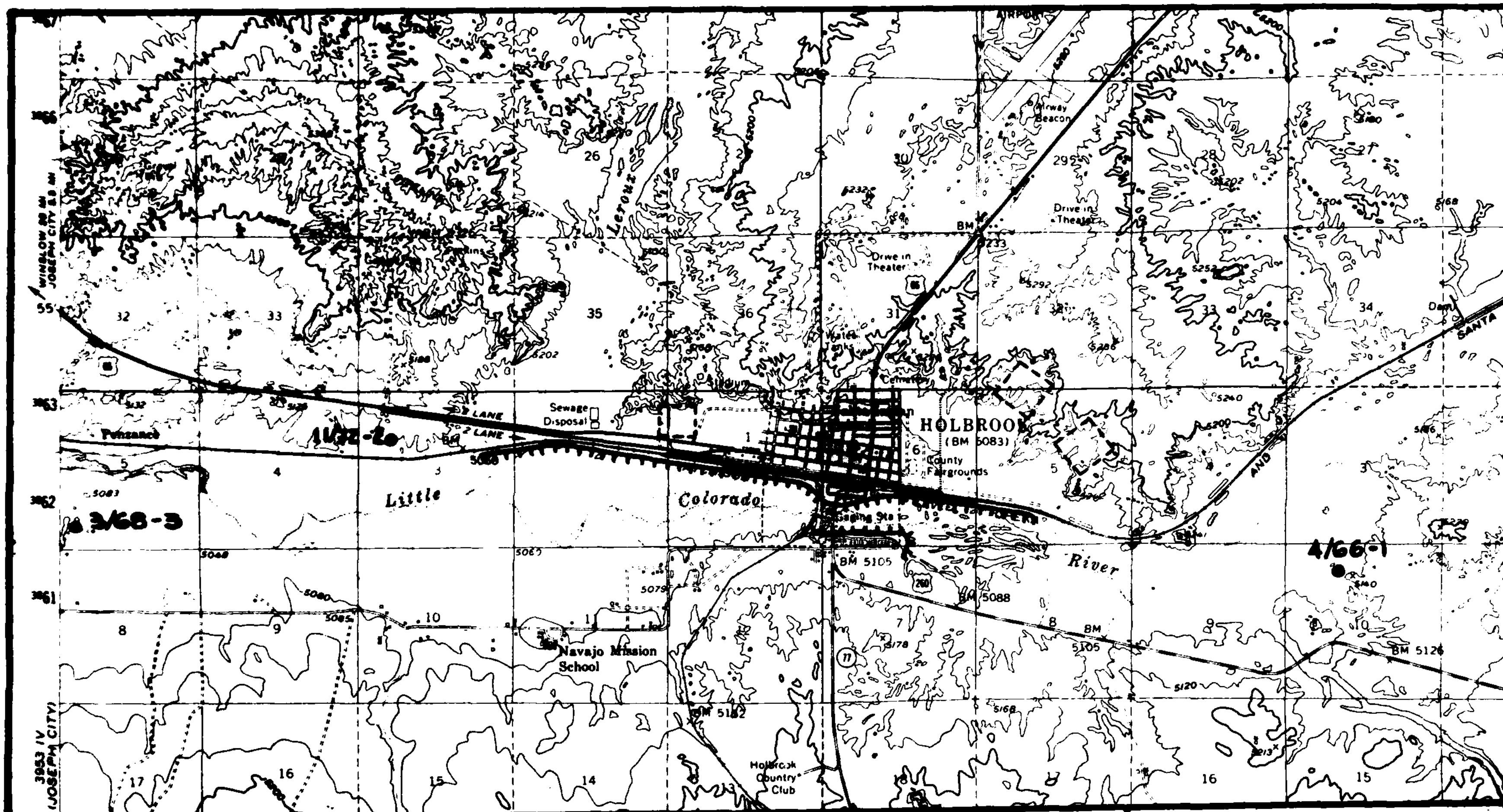
REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

PLAN AND PROFILE
SOUTH LEVEE
STA. 253+00 TO STA. 373+90
DOUBLE LEVEE PLAN (SPF)

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES CORPS OF ENGINEERS

PLATE D-4

2



KEY

● 3/68-3 WELL LOCATION

PROPOSED BORROW AREA

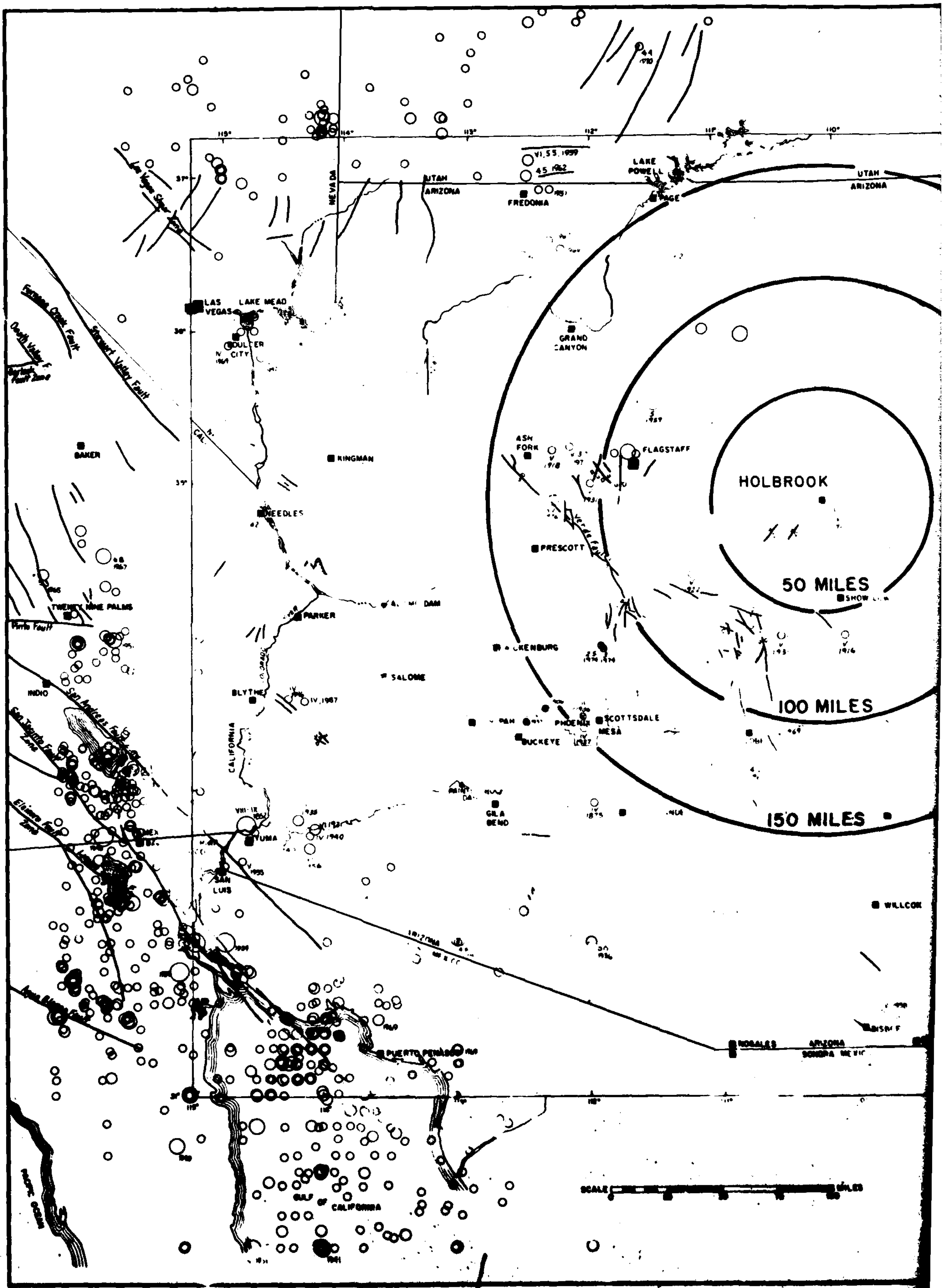
PROPOSED LEVEES

LITTLE COLORADO RIVER
AT HOLBROOK ARIZONA

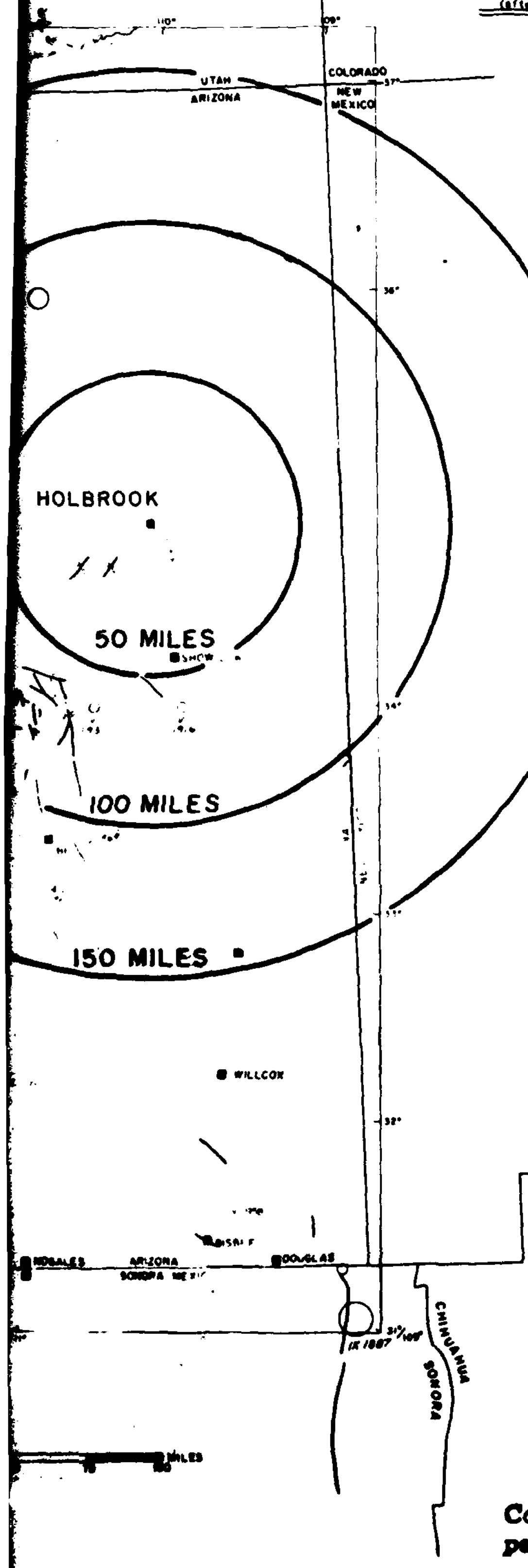
PROJECT AREA
MAP

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE D-5



HOLBROOK
50 MILES
100 MILES
150 MILES
FLAGSTAFF
ASH FORK
PRESCOTT
GRAND CANYON
FREDONIA
LAKE POWELL
PAGE
UTAH
ARIZONA
NEVADA
CALIFORNIA
LAS VEGAS
LAKE MEAD
BOULDER CITY
KINGMAN
NEEDLES
PARKER
BLYTHE
SALOME
PHOENIX
SCOTTSDALE
MESA
BUCKEYE
GILA BEND
YUMA
SAN LUIS
BAKER
TWENTY NINE PALMS
INDIO
WILLCOX
NOGALES
PUERTO PENASCO
GULF OF CALIFORNIA
PACIFIC OCEAN
SONORA MEXICO
San Andreas Fault
San Jacinto Fault Zone
Elsinore Fault Zone
Garlock Fault Zone
Death Valley F.
Furnace Creek Fault
Stewart Valley Fault
Las Vegas Shear Zone
Pinto Fault
Agua Blanca Fault
SCALE
MILES



MAGNITUDE/INTENSITY CHART

Magnitude--Approx. Richter Equivalent (after Richter)	Modified Mercalli Intensity (damage) Scale of 1931 (abridged)	
2	I.	Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel Scale)
	II.	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel Scale)
3	III.	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel Scale)
4	IV.	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV V Rossi-Forel Scale)
	V.	Felt by nearly everyone, many awakened. Some dishes, windows, etc. broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel Scale)
5	VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved, a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale)
6	VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction, slight to moderate in well built ordinary structures, considerable in poorly built or badly designed structures, some chimneys broken. Noticed by persons driving motorcars. (VIII Rossi-Forel Scale)
	VIII	Damage slight in specially designed structures, considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII+ to IX Rossi-Forel Scale)
7	IX	Damage considerable in specially designed structures, well designed frame structures thrown out of plumb, great in substantial buildings with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel Scale)
	X	[illegible] wooden structures destroyed; [illegible] and frame structures destroyed [illegible], ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel Scale)
8+	XI	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
	XII	Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown upward into the air.

LEGEND

⊙ V 1918	Earthquake epicenter, giving intensity (from Modified Mercalli Scale of 1931) in Roman numerals, and year of quake. Where no intensity is given, it is not known.
⊙ 4.1 1963	Earthquake of known magnitude, according to the Richter Scale.
●	Location and intensities (both estimated), from Palo Verde Nuclear Generating Station Report, Arizona Public Service Co, 1975
⊙ IV 4.5 1959	Earthquake of known magnitude and intensity.
●	$M<4.0$
○	$4.0 \leq M < 5.0$
○	$5.0 \leq M < 6.0$
○	$6.0 \leq M < 7.0$
○	$7.0 \leq M < 8.0$
○	$8.0 \leq M$
	Magnitude of shock determined by size of circle
■	Town or city
	Larger city
U D	Quaternary fault traces, dashed where approximately located, dotted where concealed. Sawteeth on upper plate of thrust fault. U — Upthrown side D — Downthrown side

GENERAL NOTES

1. Richter Scale magnitudes are a measure of the energy release at the focus (center of the earthquake), as determined by the amplitudes produced on a seismogram. Epicenter is the point on the Earth's surface directly above the focus.
2. Intensity--expressed on the Modified Mercalli Intensity Scale of 1931--is a measure of the effects of an earthquake on people and objects, as determined by experienced observers (See chart on this sheet. Approximate equivalents of intensity and magnitude are shown.) Intensities on this sheet are recorded at the epicenters.
3. Earthquake information gathered from U.S. Dept. of Commerce publication, United States Earthquakes (1938 through 1971), and from U.S. Dept. of Commerce Environmental Data Service, Boulder, Colorado.
4. Base Map from the Atlantic-Richfield Co. Map 1962 and Arizona Department of Transportation Map of 1970
5. Rossi-Forel Scale shown in chart is still used by some countries to evaluate earthquake effects.
6. Center of Phoenix is used as focal center of mileage rings.
7. Longest Quaternary fault within 100 miles of Phoenix is 33 miles long.
8. Only earthquakes greater than 4 magnitude are shown outside of the 150 mile radius circle.
9. Earthquake of Dec. 30, 1934 in Mexico--intensity felt in the vicinity of Phoenix was reported as III.
Earthquake of May 18, 1940 near Imperial, Cal.--intensity felt in the vicinity of Phoenix was reported at about IV.
Earthquake of Apr. 10, 1947 near Barstow (VII)--intensity felt in vicinity of Phoenix was IV.

Prior to 1974, 5 earthquakes were reportedly felt at Phoenix, (i.e. 1903, 1906 (2), 1934 and 1937). These have no instrumentally located epicenters within Arizona. Of six events felt in Phoenix, two have epicenters in Baja and one near Flagstaff. (Sturgul and Irwin, 1971)

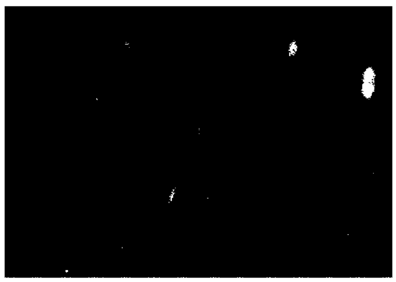
REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

LITTLE COLORADO RIVER
HOLBROOK, ARIZONA

STRUCTURAL FEATURES AND LOCATIONS OF EARTHQUAKE EPICENTERS IN ARIZONA

PLATE D-6



Section E

ECONOMIC EVALUATION OF ALTERNATIVES

Contents

Tables

CONTENTS - Continued

Tables--Continued

Figure

Section E

ECONOMIC EVALUATION OF ALTERNATIVES

1. This section economically evaluates each of the detailed alternative plans of improvement. Three measures of economic efficiency were utilized in analyzing each of these alternatives: benefit-to-cost ratio, net benefits, and internal rate of return. The benefit-to-cost ratio indicates whether a given proposal analyzed at the rate of return estabished by the Water Resources Council (currently 7-1/8 percent) would return more in benefits than it would cost. The net benefits, however, represent the difference between the benefits and the costs, analyzed at the Water Resources Council discount rate. The maximum net benefits indicate the scale of the project returning the greatest excess of benefits over costs. The internal rate of return indicates the interest rate where costs of the project equal the benefits over the period of analysis or where the benefit-to-cost ratio equals one (1.0:1). (See table E-1 at the end of this section.)

METHODOLOGY

2. The estimates of the project costs and benefits for each alternative were based on September 1979 price levels. The levee alternatives were assumed to be operative for 100 years and the floodproofing alternative for 40 years. Sufficient allowance was made for annual operation and maintenance costs to insure the long-range functioning of each project. The construction costs were converted into annual payments over the life of the project, using a discount rate of 7-1/8 percent. Operation and maintenance costs were then added to arrive at the total annual charges.

3. The levee plans were designed to reduce flood damages and hazards and to provide increased and improved recreational opportunities. The floodproofing plan would reduce flood damages and hazards. Flood damages prevented were calculated by comparing the damages that would be expected to occur over the project life without a project with those damages that would be expected to occur with a project in place.

4. Hydraulic studies were made to determine the extent of the overflow area, the depth of inundation, and the velocity of flow for each flood magnitude.

5. Depth-damages relationships were used to evaluate the impact of the anticipated flows on development in the flood plain. These relationships, which were developed for each land-use category from the local historical flood-damage reports, have been verified and adjusted for different hydrological conditions after each flood in the Los Angeles District. Depth-damage curves (shown in table E-2), when applied to damageable property, were used to develop unit flood damages (damages per unit of development).

6. Tables E-3, E-4, and E-5 show unit damages from various floods, with and without the affluence factor. Unit damages by flood and land use were then multiplied by the number of units to calculate estimated damages (table E-6). Table E-7 presents damages from interior flooding (tributaries to the Little Colorado River at Holbrook).

7. Income losses and emergency cost reflect lost wages to the residents and cleanup cost for businesses and homes in the flood plain. A regression analysis was made correlating depth of flooding with (a) days spent at home cleaning up after a flood for residential uses and (b) days establishments closed for commercial uses because of flooding. Commercial business losses were calculated by considering the length of cleanup time and wages expended only on cleanup. Lost wages were computed by using the mean family income ($11,700) of residents in the flood plain. The lost wages were related to depth of inundation. With the exception of no attempt was made to estimate the floodfighting, evacuation, and other emergency cost.

8. Damages for each type of land us and business and emergency losses were summed for each flood. The damage-discharge relationship for project year one conditions is shown on plate E-1.

9. The damages expected to result from each size flood were weighted by the probability of occurrence of that flood by combining the damage-discharge and discharge-frequency curves. Average annual damages were then calculated by using standard damage-frequency integration techniques. The discharge-frequency and damage-frequency curves are also shown on plate E-1. Equivalent annual damages were computed next by summing the present worths of average annual damages and applying the capital recovery factor (partial payment series) for a 7-1/8 percent discount rate. Table E-8 presents the average and equivalent annual damages for the flood plain without the project; included in the table are the damages from flooding by both the Little Colorado River and interior drainage. Damages increase during the first 50 years of project life due to aggradation of the riverbed and productivity increases on contents of residential property.

10. To evaluate the impact of each alternative plan, the frequency curves associated with the improvements were used, with adjustments made for the new channel capacities. These curves were then applied to the basic damage-discharge curves. Average annual damages remaining with the project in place were calculated by integrating the "with project" frequency curves and the damage-discharge curves. Equivalent annual damages were calculated at a 7-1/8 percent discount rate for the appropriate project life. Average annual and equivalent annual damages remaining with each alternative are shown in table E-9.

11. Flood-damage-reduction benefits attributable to each plan are the difference between the damages without the plan and the damages remaining with each alternative. Damages prevented are shown in table E-10.

AD-A136 661 REVIEW REPORT FOR FLOOD CONTROL AND RECREATIONAL DEVELOPMENT LITTLE COLOR..(U) ARMY ENGINEER DISTRICT LOS ANGELES CA SEP 80 3/4

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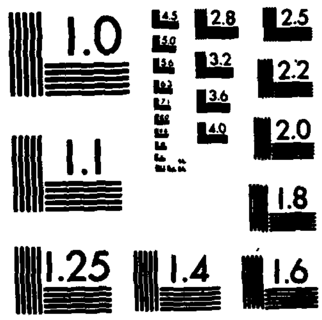


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

12. The flood control costs for two of the three alternatives presented are economically justified under present conditions of development. This is demonstrated in table E-1 where the benefit-to-cost ratio for each alternative under present conditions is given.

13. The impact of growth in personal income was measured for present and future development by assuming no growth in damageable residential values. In accordance with ER 1105-5-351, and due to the uncertainty of projecting future per-capita consumption of damageable items, the future value of contents was limited to a maximum of 75 percent of structural value.

PRESENT LAND USE

14. The overflow area of the Little Colorado River in the vicinity of Holbrook is primarily in natural uses. Of the 2,600 acres subject to inundation by a standard project flood (SPF), 500 are in urban use. All of this urban area is within easy access of U.S. Highway 66 or Interstate 40. Approximately 632 homes and 26 mobile homes are within the SPF overflow area. Much of the property in the SPF overflow area is tourist-related commercial (motels, service stations, restaurants, and Indian jewelry stores). Tables E-11 and E-12 show the present land use in the flood plain of the Little Colorado River and in the area flooded by interior drainage.

PRESENT VALUES OF DAMAGEABLE PROPERTY

15. Present (1979) values of developments in the overflow area were obtained from many sources. Estimates of improvement values for private property were made by (a) sampling development carried on the Navajo County tax assessor's books and adjusting the assessed valuation to market value, (b) consulting knowledgeable real estate brokers for valuation data, and (c) performing field inspections and appraisals of development using references, such as the Marshall valuation services. To determine the value of residential contents, the Los Angeles District made a survey of 18 insurance companies and claims adjusters. Information on homeowners' fire insurance policies was sought from these experts, who were asked specifically about the value of contents in houses that had been compleely destroyed in order to exclude any smoke damage that might skew content damages. They reported that settlement for contents generally ranged from 40 to 60 percent. Some informal sampling by the District in the Holbrook area confirmed these figures. The average value of contents from homes in the overflow area is estimated at 40.5 percent of the structural value. Commercial values were based on recent values obtained for establishments on a square-foot basis. Public property values were obtained from appropriate governmental agencies. Unit values of present development are shown in table E-13.

FUTURE VALUES OF DAMAGEABLE PROPERTY

16. Future development for Holbrook was projected to meet the expected increase in population through 1990. None of this development is expected to locate within the flood plain fringe.

17. The future value of contents per residence was projected at the OBERS rate of increase in personal per-capita income (2.6 percent annually). The value of future contents increased to a maximum of 75 percent of the value of the structure in conformance with ER 1105-2-351. No increase in value of other existing developments was claimed. Table E-14 gives present and future values of the project subject to inundation.

PROJECT COSTS

18. The project costs include the estimated first costs for the project and the annual charges for each project feature of each alternative.

First Costs

19. The estimated first costs for the project include estimates for construction, engineering, design, supervision and administration, relocation, rights-of-way, beautification, mitigation, and an allowance for contingencies. Unit prices were developed by using current (September 1979) material, equipment, and labor costs for the basic facilities, as well as the cost for additional land. To appraise the land costs, the sites of the recommended improvements were inspected and the real estate markets concerned were analyzed. The cost of rights-of-way, which includes acquisition costs, is based on developments currently in place. Table E-1 shows the first costs of each alternative by project feature and purpose.

Annual Charges

20. Estimates were made of the time it would take to construct each feature of each alternative. No interest during construction was charged as all items would be operational and would be accruing benefits within a year after construction was initiated. Total first costs were converted to annual payments by applying the capital recovery factor at the current interest rate of 7-1/8 percent for 100 years for levee alternatives, and 40 years for the floodproofing alternatives. To this annual payment was added the estimated annual charge for operation and maintenance of the project. Annual charges thus include (a) interest and amortization the total investment over the project life, and (b) average annual costs of project maintenance and operation. Table E-1 shows the annual charges computed for each project feature of each alternative.

PROJECT BENEFITS

21. Most alternative plans were formulated for multipurpose use of the flood plain resources. Recognition was also given to nonquantifiable beneficial impact, such as the reduction in the threat to loss of life, the decrease in disease hazard, and the cost of the severe economic and social dislocation caused by large floods, which did not lend themselves to quantification and, therefore, do not appear explicitly in the benefit estimates.

22. Alternatives to the base condition (no action plan) provide a variety of benefits. Structural alternatives, the single-levee and double-levee plans, provide flood control and recreation benefits. The floodproofing plan provides flood control benefits only.

Flood Control Benefits

23. Quantifiable flood control benefits, discussed in the following paragraphs, include flood damage reduction, advanced replacement of bridges, and reduction in insurable losses.

24. REDUCTION IN INSURABLE LOSSES TO HOUSES THAT ARE PERMANENTLY EVACUATED.. This benefit category recognizes losses that are incurred by residents of the flood plain but are borne by the general public. These losses are transmitted to the general public through subsidized flood insurance. Insurable losses are calculated by first determining probable annual and then equivalent annual damages. Expected annual deductable costs and insurance premiums are subtracted from equivalent annual damages to give equivalent annual benefits for reduction in insurable losses.

(Equivalent Annual Damages) - (Expected Annual Deductible Costs + Annual Insurance Premiums = Reduction in insurable losses

Single-levee	\$12,000 - \$1,600 = \$10,400	say \$10,000
Double-levee	\$ 5,000 - \$ 360 = \$ 4,640	say \$ 5,000

25. FLOOD DAMAGE REDUCTION. The flood damage-reduction category reflects the savings attributable to the prevention of direct damages inflicted by floodwaters on real and personal property. Also included is some measure of the reduction of nonphysical losses that would otherwise be experienced by residents of the area in terms of lost wages and loss of return on capital investments. These flood-damage-reduction benefits were estimated by evaluating damages that would occur to present and projected development if no project were constructed and then deducting the damages that would be expected to occur if each alternative plan was in place. Any such reduction during the project life was claimed as a benefit. Also, damages were a function of damageable property as well as hydrologic and topographic conditions.

26. MAXIMIZATION OF NET BENEFITS. An analysis was performed to determine the scale of development that maximized net annual economic benefits. The analysis was performed for the tentatively selected plan (double-levee plan) only. The analysis for the single-levee plan would

be similar. Figure E-2 graphically presents this analysis, and shows that the optimum scale of development is an SPF design. Maximization was not carried beyond SPF (1000 year) because of extreme limitations in accurancy in dealing with such rare events.

27. EMPLOYMENT. Employment benefits are an adjustment to the cost of a project that identifies the use of an otherwise unemployed resource. Specifically, these benefits are identified as payments to unemployed labor resources directly employed in the construction and installation of a plan. The most recent (October 1979) unemployment rate in Navajo County was 8.7 percent. The county has been designated a Title IV in EDA qualified area by the Department of Commerce since February 1970, which classifies the county as being eligible for redevelopment assistance.

28. In accordance with ER 1105-2-351 benefits were taken for the short term increase in employment that would be created by the construction of any of the alternatives. The one levee alternative will create 220 person weeks of work, the two levee alternative 256 person weeks and the floodproofing alternate 2959 person weeks. The employment benefit calculations for each alternative follows:

Single levee alternative-200 wks x 40 hrs x $10.61 x .55 x .07132 = $3,662
say $4,000

Double levee alternative-256 wks x 40 hrs x $10.61 x .55 x .07132 = $4,261
say $4,000

Floodproofing- 2960 wks x 40 hrs x $10.61 x .55 x .07132 = $49,276
say $49,000

Recreational Benefits

29. Recreation benefits will derive from the construction of a picnic area and a bicycle trail. Located in the ponding area north of the river, the picnic area will have 10 picnic tables. The bicycle trail will be 3 miles long and is to be on the north levee of either the one-levee or two-levee plans. The per-capita demand for bicycle trails and picnic areas were derived from the "State of Arizona Statewide Comprehensive Recreation Plan" for Planning District 3, which includes Navajo County. Table E-15 shows recreational benefit calculations.

The first cost for the bicycle trail and picnic area is $83,000. The annual cost of recreation for this project is $16,000, and the equivalent annual benefits are $25,000, thus providing a benefit-to-cost ratio of 1.6 to 1.

SENSITIVITY ANALYSIS

30. The sensitivity analysis was confined to flood control as recreation does not affect project formulation. The flood control costs for two of three alternatives presented are economically justified under

present conditions of development. This is demonstrated in table E-1 where the benefit-to-cost ratio for each alternative under present conditions is given.

31. As a check on the sensitivity of the net benefits to the discount rate, that rate at which benefits from flood control would equal costs for flood control improvements was determined and is shown in table E-1.

ECONOMIC SUMMARY

The Little Colorado River

32. The economic justification and a comparison of the first costs, the average annual costs and benefits, and the benefit/cost ratio of each alternative for flood control on the Little Colorado River at Holbrook are shown in table E-1.

33. The levee alternatives differ in benefits by an equivalent annual amount of $2,000 because the double-levee plan induces damages to the State Highway 77 bridge. The floodproofing alternative is considered to be only seventy percent effective because of continuing yard and vehicle damages.

Tributaries to the Little Colorado River

34. The feasibility of providing protection to development in the City of Holbrook from flooding by tributaries of the Little Colorado River was studied. Flows from tributaries originating north of town and west of Navajo Boulevard can cause what might be characterized as nuisance flooding. Except for rare events, flooding would occur only on streets and lawns. The 50-year flood (see plate A-3) could produce some isolated flooding inside buildings. A 100 year event could cause outside-structure depths of 0.5 to over 2.0 feet. Flow velocities would range from 1 to 5 feet per second. Equivalent annual damages from tributary flooding are estimated at $48,000 (7-1/8 percent - 100 years). Because current authority precludes Corps participation in solving urban flood problems on streams with 10-year discharges less than 800 cfs and 100-year discharges less than 1,800 cfs, this problem was not pursued. However, the residual problem is displayed in the Systems of Accounts display under "Formulation, Assessment and Evaluation of Detailed Plans."

35. Each alternative prevents some damages from tributary flooding; however the floodproofing alternative prevents most damages caused by the tributaries.

Table E-1. Economic summary.
(In thousands of dollars.)
(7-1/8%)

	Single levee	Double levee	Flood proofing
First cost			
Flood control			
Construction, rights of way, relocations	9,158	9,386	18,650
Supplemental housing payments	570	165	0
Total flood control	9,728	9,551	18,650
Recreation	83	83	0
Total first cost	9,811	9,634	18,650
Annual charges			
Flood control			
Amortization and interest*	653	669	1,419
Operation and maintenance	44	49	0
Total flood control	697	718	1,419
Recreation			
Amortization and interest	6	6	0
Operations and maintenance	10	10	0
Total Recreation	16	16	0
Total annual charges	713	734	1,419
Annual benefits (future conditions included)			
Flood control			
Damages prevented - main stem	1,572	1,586	1,117
Damages prevented - interior drainage	2	2	42
Employment	4	4	49
Reduction in insurable losses	10	5	0
Reduction in emergency cost - south side	10	2	0
Total flood control	1,598	1,599	1,208
Recreation			
Recreational use	25	25	0
Total recreation	25	25	0
Total project annual benefits	1,623	1,624	1,208
B/C ratio flood control existing conditions*	1.8	1.8	0.7
B/C ratio flood control future conditions*(1)	2.3	2.2	0.85
B/C ratio recreation	1.6	1.6	—
B/C ratio total project (future conditions)*	2.3	2.2	0.9
Net benefits flood control*	901	881	-211
Net benefits recreation	9	9	0
Net benefits total project*	910	890	-211
Internal rate of return, flood control	16.4%	15.9%	5.8%

* Cost for supplemental housing payments are not included in the annual charges and benefit-to-cost ratio in accordance with ER 1165-2-117.

(1) Includes productivity increase and allowance for future sedimentation.

Table E-2. Depth-damage curves (in percentages).

Land use	Depth (ft) 0	1	3	5	7	9
Single famly residential						
Contents	0	5	58	80	100	100
Conventional (structural)	0	12	31	35	52	55
Mobile homes (structural)	0	12	35	43	65	68
Commercial						
Auto repair and sales	0	10	38	64	65	65
Strip	0	11	40	54	60	60
Two-story	0	6	15.5	17.5	26	27.5
Motels	0	12	35	43	65	68
Restaurants	0	10	38	64	65	65
Gas stations	0	6	15.5	17.5	26	27.5
Public						
Office	0	11	40	54	60	60
Schools	0	11	40	54	60	60
Semipublic						
Churches	0	12	31	35	52	55
Industrial						
Warehouses	0	10	38	64	65	65
Manufacturing	0	10	38	64	65	65

Table E-3. Unit damages by flood and property type with affluence factors.
(In thousands of dollars)

Land use	1979	1985	1995	2005	2015	2025	2035-2085
STANDARD PROJECT FLOOD							
Single family residential							
Conventional	12.8	13.9	15.7	17.4	17.4	17.4	17.4
Mobile homes	10.5	11.4	12.8	13.4	13.4	13.4	13.4
Commercial							
Auto repair and sales	45.2	45.2	45.2	45.2	45.2	45.2	45.2
Strip	47.8	47.8	47.8	47.8	47.8	47.8	47.8
Two-story	25.8	25.8	25.8	25.8	25.8	25.8	25.8
Motels	140.6	140.6	140.6	140.6	140.6	140.6	140.6
Restaurants	58.3	58.3	58.3	58.3	58.3	58.3	58.3
Gas stations	35.2	35.2	35.2	35.2	35.2	35.2	35.2
Public							
Office	45.7	45.7	45.7	45.7	45.7	45.7	45.7
Schools	648.4	648.4	648.4	648.4	648.4	648.4	648.4
Semipublic							
Churches	33.0	33.0	33.0	33.0	33.0	33.0	33.0
Industrial							
Warehouses	75.8	75.8	75.8	75.8	75.8	75.8	75.8
Manufacturing	5.1	5.1	5.1	5.1	5.1	5.1	5.1

Table E-3. Continued.

Land use	1979	1985	1995	2005	2015	2025	2035-2085
			100-YEAR FLOOD				
Single family residential							
Conventional	11.4	12.4	14.2	15.8	15.8	15.8	15.8
Mobile homes	8.2	8.9	10.2	10.6	10.6	10.6	10.6
Commercial							
Auto repair and sales	44.3	44.3	44.3	44.3	44.3	44.3	44.3
Strip	47.0	47.0	47.0	47.0	47.0	47.0	47.0
Two-story	24.8	24.8	24.8	24.8	24.8	24.8	24.8
Motels	123.7	123.7	123.7	123.7	123.7	123.7	123.7
Restaurants	57.3	57.3	57.3	57.3	57.3	57.3	57.3
Gas stations	28.1	28.1	28.1	28.1	28.1	28.1	28.1
Public							
Office	44.4	44.4	44.4	44.4	44.4	44.4	44.4
Schools	509.8	509.8	509.8	509.8	509.8	509.8	509.8
Semipublic							
Churches	30.3	30.3	30.3	30.3	30.3	30.3	30.3
Industrial							
Warehouses	67.1	67.1	67.1	67.1	67.1	67.1	67.1
Manufacturing	4.7	4.7	4.7	4.7	4.7	4.7	4.7

Table E-3. Continued.

Land use	1979	1985	1995	2005	2015	2025	2035-2089
			50-YEAR FLOOD				
Single family residential							
Conventional	10.6	11.6	13.2	14.8	14.8	14.8	14.8
Mobile homes	7.8	8.4	9.6	10.0	10.0	10.0	10.0
Commercial							
Auto repair and sales	43.9	43.9	43.9	43.9	43.9	43.9	43.9
Strip	45.8	45.8	45.8	45.8	45.8	45.8	45.8
Two-story	24.3	24.3	24.3	24.3	24.3	24.3	24.3
Motels	119.1	119.1	119.1	119.1	119.1	119.1	119.1
Restaurants	54.5	54.5	54.5	54.5	54.5	54.5	54.5
Gas stations	27.7	27.7	27.7	27.7	27.7	27.7	27.7
Public							
Offices	44.1	44.1	44.1	44.1	44.1	44.1	44.1
Schools	491.3	491.3	491.3	491.3	491.3	491.3	491.3
Semipublic							
Churches	29.8	29.8	29.8	29.8	29.8	29.8	29.8
Industrial							
Warehouses	49.0	49.0	49.0	49.0	49.0	49.0	49.0
Manufacturing	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Table E-4. Unit damages by flood and property type without affluence factors.
(In thousands of dollars)
(1979 prices)

Land use	1979	1985	1995	2005	2015	2025	2035-2085
				STANDARD PROJECT FLOOD			
Single family residential							
Conventional	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Mobile homes	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Commercial							
Auto repair and sales	45.2	45.2	45.2	45.2	45.2	45.2	45.2
Strip	47.8	47.8	47.8	47.8	47.8	47.8	47.8
Two-story	25.8	25.8	25.8	25.8	25.8	25.8	25.8
Motels	140.6	140.6	140.6	140.6	140.6	140.6	140.6
Restaurants	58.3	58.3	58.3	58.3	58.3	58.3	58.3
Gas stations	35.2	35.2	35.2	35.2	35.2	35.2	35.2
Public							
Office	45.7	45.7	45.7	45.7	45.7	45.7	45.7
Schools	648.4	648.4	648.4	648.4	648.4	648.4	648.4
Semipublic							
Churches	33.0	33.0	33.0	33.0	33.0	33.0	33.0
Industrial							
Warehouses	75.8	75.8	75.8	75.8	75.8	75.8	75.8
Manufacturing	5.1	5.1	5.1	5.1	5.1	5.1	5.1

Table E-4. Continued.

Land use	1979	1985	1995	2005	2015	2025	2035-2085
100-YEAR FLOOD							
Single family residential							
Conventional	11.4	11.4	11.4	11.4	11.4	11.4	11.4
Mobile homes	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Commercial							
Auto repair and sales	44.3	44.3	44.3	44.3	44.3	44.3	44.3
Strip	47.0	47.0	47.0	47.0	47.0	47.0	47.0
Two-story	24.8	24.8	24.8	24.8	24.8	24.8	24.8
Motels	123.7	123.7	123.7	123.7	123.7	123.7	123.7
Restaurants	57.3	57.3	57.3	57.3	57.3	57.3	57.3
Gas stations	28.1	28.1	28.1	28.1	28.1	28.1	28.1
Public							
Office	44.4	44.4	44.4	44.4	44.4	44.4	44.4
Schools	509.8	509.8	509.8	509.8	509.8	509.8	509.8
Semipublic							
Churches	30.3	30.3	30.3	30.3	30.3	30.3	30.3
Industrial							
Warehouses	67.1	67.1	67.1	67.1	67.1	67.1	67.1
Manufacturing	4.7	4.7	4.7	4.7	4.7	4.7	4.7

Table E-4. Continued.

Land use	1979	1985	1995	2005	2015	2025	2035-2085
50-YEAR FLOOD							
Single family residential							
Conventional	10.6	10.6	10.6	10.6	10.6	10.6	10.6
Mobile homes	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Commercial							
Auto repair and sales	43.9	43.9	43.9	43.9	43.9	43.9	43.9
Strip	45.8	45.8	45.8	45.8	45.8	45.8	45.8
Two-story	24.3	24.3	24.3	24.3	24.3	24.3	24.3
Motels	119.1	119.1	119.1	119.1	119.1	119.1	119.1
Restaurants	54.5	54.5	54.5	54.5	54.5	54.5	54.5
Gas stations	27.7	27.7	27.7	27.7	27.7	27.7	27.7
Public							
Office	44.1	44.1	44.1	44.1	44.1	44.1	44.1
Schools	491.3	491.3	491.3	491.3	491.3	491.3	491.3
Semipublic							
Churches	29.8	29.8	29.8	29.8	29.8	29.8	29.8
Industrial							
Warehouses	49.0	49.0	49.0	49.0	49.0	49.0	49.0
Manufacturing	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Table E-5. Incremental unit damages from affluence factor by flood and property type.
(In thousands of dollars.)

Land use	1979	1985	1995	2005	2015	2025	2035-2085
STANDARD PROJECT FLOOD							
Single family residential							
Conventional	0	1.1	1.8	1.7	0	0	0
Mobile homes	0	0.9	1.4	0.6	0	0	0
100-YEAR FLOOD							
Single family residential							
Conventional	0	1.0	1.8	1.6	0	0	0
Mobile homes	0	.7	1.3	0.4	0	0	0
50-YEAR FLOOD							
Single family residential							
Conventional	0	1.0	1.6	1.6	0	0	0
Mobile homes	0	0.6	1.2	0.4	0	0	0

Table E-6. Estimated present (Sept. 1979) damages by property type in various floods - Little Colorado River (In thousands of dollars)

Land use	SPF	100-Year	50-Year
Single-family residential			
Conventional			
Structures	4,550	3,709	3,426
Contents	3,543	3,149	2,957
Mobile homes			
Structures	157	118	114
Contents	115	96	88
Commercial			
Auto repair and sales	588	576	571
Strip	3,588	3,528	3,438
Two-story	103	99	97
Motels	2,530	2,227	2,144
Restaurants	700	630	599
Gas stations	493	394	388
Public			
Office	686	666	661
Schools	7,132	5,098	4,913
Industrial			
Warehouses	758	671	490
Manufacturing	76	71	38
Semipublic	330	303	298
Income losses & emergency costs	754	615	550
Roads and highways	564	100	80
Railroads; bridges and tracks	1,000	700	350
Total	27,617	22,079	21,202

Table E-7. Estimated present (Sept. 1979) damages by property type and discharge - interior drainage.
(In thousands of dollars.)

Land use	3,000 cfs	2,000 cfs	1,000 cfs
Single family residential			
Conventional			
Structures	812	592	378
Contents	360	181	66
Mobile homes			
Structures	8	7	2
Contents	1	1	0
Commercial			
Auto repair and sales	34	14	3
Strip	398	191	61
Two-story	8	4	1
Motels	375	298	129
Restaurants	52	40	11
Gas stations	18	12	6
Public			
Office	160	115	75
Schools	250	180	72
Industrial			
Warehouses	0	0	0
Manufacturing	0	0	0
Semipublic	89	72	55
Income losses & emergency cost	81	55	30
Roads and highways	40	20	8
Railroad; tracks and bridges	6	1	0
Total	2,692	1,783	897

Table E-8. Average and equivalent annual damages without project.
(In thousands of dollars.)

Land use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 years)
Damages from Flooding by the Little Colorado River								
Single family residential								
Conventional								
Structures	203	203	229	252	278	299	317	239
Contents	173	207	295	395	433	466	490	323
Mobile homes								
Structures	7	7	7	8	9	10	10	8
Contents	5	6	6	10	12	12	13	9
Commercial								
Auto repair and sales	33	33	37	40	44	47	50	38
Strip	197	197	221	244	268	287	302	231
Two-story	6	6	6	7	8	8	9	7
Motels	125	125	140	155	170	182	192	146
Restaurants	35	35	39	43	48	51	54	41
Gas stations	23	23	25	28	31	33	35	27
Public								
Office	38	38	38	42	47	51	55	44
Schools	291	291	326	362	397	428	450	342
Industrial								
Warehouses	31	31	35	39	43	47	51	37
Manufacturing	3	3	3	4	4	4	5	4
Semipublic	17	17	19	21	23	25	26	20
Income losses & emergency cost	42	42	48	52	56	59	61	49
Streets, highways, and bridges	15	15	15	15	15	15	15	15
Railroad, tracks, and bridges	64	64	64	64	64	64	64	64
Subtotal	1,308	1,343	1,543	1,781	1,003	2,088	2,179	1,644

Table E-8. Continued.

Land use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
Damages from Flooding by the Little Colorado River								
Single-family residential								
Conventional								
Structures	24	24	24	24	24	24	24	24
Contents	5	6	8	10	10	10	10	9
Mobile homes								
Structures	0	0	0	0	0	0	0	0
Contents	0	0	0	0	0	0	0	0
Commercial								
Auto repair and sales								
Strip	2	2	2	2	2	2	2	2
Two-story	0	0	0	0	0	0	0	0
Motels	3	3	3	3	3	3	3	3
Restaurants	0	0	0	0	0	0	0	0
Gas stations	0	0	0	0	0	0	0	0
Public								
Office	2	2	2	2	2	2	2	2
Schools	6	6	6	6	6	6	6	6
Industrial								
Warehouses	0	0	0	0	0	0	0	0
Manufacturing	0	0	0	0	0	0	0	0
Semipublic								
Income losses	1	1	1	1	1	1	1	1
Streets, highways, and bridges	1	1	1	1	1	1	1	1
Railroad, tracks, and bridges	0	0	0	0	0	0	0	0
Subtotal	44	45	47	49	49	49	49	48
Total	1,352	1,388	1,600	1,830	1,952	2,137	2,148	1,692

Table E-9. Average and Equivalent annual residual damages.
(In thousands of dollars.)

Land use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
Residual Damages from Flooding by the Little Colorado River								
Single family residential								
Conventional								
Structures	6	6	6	6	6	6	11	6
Contents	4	5	6	8	8	8	17	7
Mobile homes								
Structures	0	0	0	0	0	0	0	0
Contents	0	0	0	0	0	0	0	0
Commercial								
Auto repair and sales	1	1	1	1	1	1	2	1
Strip	4	4	4	4	4	4	11	5
Two-story	0	0	0	0	0	0	0	0
Motels	3	3	3	3	3	3	7	4
Restaurants	1	1	1	1	1	1	2	1
Gas stations	1	1	1	1	1	1	1	1
Public								
Office	1	1	1	1	1	1	2	1
Schools	9	9	9	9	9	9	18	10
Industrial								
Warehouses	1	1	1	1	1	1	2	1
Manufacturing	0	0	0	0	0	0	0	0
Semipublic	0	0	0	0	0	0	0	0
Income losses & emergency	0	0	0	0	0	0	0	0
Streets, highways, and bridges	12	12	12	12	12	12	12	12
Railroad, tracks, and bridges	1	1	1	1	1	1	1	1
Subtotal	44	45	46	48	48	48	86	50

Table E-9. Continued

Land use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
	Residual Damages from Flooding by Interior Drainage							
Single family residential								
Conventional								
Structures	22	22	22	22	22	22	22	22
Contents	5	6	8	10	19	19	19	9
Mobile homes								
Structures	0	0	0	0	0	0	0	0
Contents	0	0	0	0	0	0	0	0
Commercial								
Auto repair and sales								
Strip	2	2	2	2	2	2	2	2
Two-story	0	0	0	0	0	0	0	0
Motels	3	3	3	3	3	3	3	3
Restaurants	0	0	0	0	0	0	0	0
Gas stations	0	0	0	0	0	0	0	0
Public								
Office	2	2	2	2	2	2	2	2
Schools	6	6	6	6	6	6	6	6
Industrial								
Warehouses	0	0	0	0	0	0	0	0
Manufacturing	0	0	0	0	0	0	0	0
Semipublic								
Income losses	1	1	1	1	1	1	1	1
Streets, highways, and bridges	1	1	1	1	1	1	1	1
Railroad, tracks, and bridges	0	0	0	0	0	0	0	0
Subtotal	42	43	45	47	47	47	47	46
Total, single levee plan	86	88	91	95	95	95	133	96

Table E-9. Continued

Alternative double-levee

Land use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
Residual Damages from Flooding by the Little Colorado River								
Single family residential								
Conventional								
Structures	6	6	6	6	6	6	11	6
Contents	4	5	6	8	8	8	17	7
Mobile homes								
Structures	0	0	0	0	0	0	0	0
Contents	0	0	0	0	0	0	0	0
Commercial								
Auto repair and sales	1	1	1	1	1	1	2	1
Strip	4	4	4	4	4	4	11	5
Two-story	0	0	0	0	0	0	0	0
Motels	3	3	3	3	3	3	7	4
Restaurants	1	1	1	1	1	1	2	1
Gas stations	1	1	1	1	1	1	1	1
Public								
Office	1	1	1	1	1	1	2	1
Schools	9	9	9	9	9	9	18	10
Industrial								
Warehouses	1	1	1	1	1	1	2	1
Manufacturing	0	0	0	0	0	0	0	0
Semipublic	0	0	0	0	0	0	0	0
Income losses & emergency cost	0	0	0	0	0	0	0	0
Streets, highways, and bridges	12	12	12	12	12	12	12	12
Railroad, tracks, and bridges	1	1	1	1	1	1	1	1
Subtotal	44	45	46	48	48	48	86	50

Table E-9. Continued

Land use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
Residual Damages from Flooding by Interior Drainage								
Single family residential								
Conventional								
Structures	22	22	22	22	22	22	22	22
Contents	5	6	8	10	10	10	10	9
Mobile homes								
Structures	0	0	0	0	0	0	0	0
Contents	0	0	0	0	0	0	0	0
Commercial								
Auto repair and sales								
Strip	2	2	2	2	2	2	2	2
Two-story								
Motels	3	3	3	3	3	3	3	3
Restaurants	0	0	0	0	0	0	0	0
Gas stations	0	0	0	0	0	0	0	0
Public								
Office	2	2	2	2	2	2	2	2
Schools	6	6	6	6	6	6	6	6
Industrial								
Warehouse	0	0	0	0	0	0	0	0
Manufacturing	0	0	0	0	0	0	0	0
Semipublic								
Income losses	1	1	1	1	1	1	1	1
Streets, highways, and bridges	1	1	1	1	1	1	1	1
Railroad, tracks, and bridges	0	0	0	0	0	0	0	0
Subtotal	42	43	45	47	47	47	47	46
Total, double-levee plan	86	88	91	95	95	95	133	96

Table E-9. Continued

Alternative floodproofing Land use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
Residual Damages from Flooding on the Little Colorado River								
Single family residential								
Conventional								
Structures	57	57	63	70	77	82	90	66
Contents	50	59	83	109	119	128	141	91
Mobile homes								
Structures	2	2	2	2	2	2	2	1
Contents	1	1	1	2	3	3	4	2
Commercial								
Auto repair and sales	9	9	10	11	12	13	14	10
Strip	52	52	58	64	70	65	84	61
Two-story	1	1	1	2	3	3	4	2
Motels	33	33	37	41	45	48	53	39
Restaurants	9	9	10	11	13	13	14	11
Gas stations	6	6	7	8	8	9	9	7
Public								
Office	10	10	10	11	12	13	15	11
Schools	79	79	88	97	106	114	126	93
Industrial								
Warehouses	8	8	9	10	12	12	14	10
Manufacturing	1	1	1	2	2	2	3	2
Semipublic	4	4	5	5	6	6	6	5
Income losses & emergency	32	32	34	36	39	40	41	37
Streets, highways, and bridges	15	15	15	15	15	15	15	15
Railroad, tracks, and bridges	64	64	64	64	64	64	64	64
Subtotal	403	442	498	560	608	632	699	527

Table E-9. Continued

Land use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
Residual Damages from Interior Drainage								
Single family residential								
Conventional								
Structures	2	2	2	2	2	2	2	2
Contents	0	1	1	1	1	1	1	1
Mobile homes								
Structures	0	0	0	0	0	0	0	0
Contents	0	0	0	0	0	0	0	0
Commercial								
Auto repair and sales	0	0	0	0	0	0	0	0
Strip	0	0	0	0	0	0	0	0
Two-story	0	0	0	0	0	0	0	0
Motels	0	0	0	0	0	0	0	0
Restaurants	0	0	0	0	0	0	0	0
Gas stations	0	0	0	0	0	0	0	0
Public								
Offices	0	0	0	0	0	0	0	0
Schools	1	1	1	1	1	1	1	1
Industrial								
Warehouses	0	0	0	0	0	0	0	0
Manufacturing	0	0	0	0	0	0	0	0
Semipublic	0	0	0	0	0	0	0	0
Income losses	0	0	0	0	0	0	0	0
Streets, highways, and bridges	0	0	0	0	0	0	0	0
Railroad, tracks, and bridges	0	0	0	0	0	0	0	0
Subtotal	3	4	4	4	4	4	4	4
Total, floodproofing plan	406	446	502	564	612	636	703	531

Table E-10. Average and equivalent annual damages prevented by alternatives
(In thousands of dollars.)

Alternative single levee

Land Use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
Damages Prevented From Flooding on the Little Colorado River								
Single family residential								
Conventional								
Structures	195	195	221	242	268	289	302	230
Contents	164	197	282	381	418	450	465	309
Mobile homes								
Structures	7	7	7	8	9	10	10	8
Contents	5	6	6	10	12	12	13	9
Commercial								
Auto repair and sales	32	32	36	38	42	45	48	37
Strip	193	193	217	240	264	283	291	226
Two-story	6	6	6	6	6	6	6	6
Motels	122	122	137	152	167	179	185	142
Restaurants	34	34	38	42	47	50	52	40
Gas stations	22	22	24	27	30	32	34	26
Public								
Office	37	37	37	41	46	50	53	43
Schools	282	282	317	353	388	419	432	332
Industrial								
Warehouses	30	30	34	38	41	46	49	36
Manufacturing	2	2	2	3	3	3	4	3
Semipublic	17	17	19	21	23	25	26	20
Income losses	32	32	38	42	46	49	51	39
Streets, highways, and bridges	3	3	3	3	3	3	3	3
Railroad, tracks, and bridges	63	63	63	63	63	63	63	63
Subtotal	1,245	1,279	1,487	1,710	1,876	2,014	2,087	1,572

Table E-10. Continued

Land Use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
	Damages Prevented from Flooding by Interior Drainage							
Single family residential								
Conventional								
Structures	2	2	2	2	2	2	2	2
Contents	0	0	0	0	0	0	0	0
Mobile homes								
Structures	0	0	0	0	0	0	0	0
Contents	0	0	0	0	0	0	0	0
Commercial								
Auto repair and sales	0	0	0	0	0	0	0	0
Strip	0	0	0	0	0	0	0	0
Two-story	0	0	0	0	0	0	0	0
Motels	0	0	0	0	0	0	0	0
Restaurants	0	0	0	0	0	0	0	0
Gas stations	0	0	0	0	0	0	0	0
Public								
Office	0	0	0	0	0	0	0	0
Schools	0	0	0	0	0	0	0	0
Industrial								
Warehouses	0	0	0	0	0	0	0	0
Manufacturing	0	0	0	0	0	0	0	0
Semipublic	0	0	0	0	0	0	0	0
Income losses	0	0	0	0	0	0	0	0
Streets, highways, and bridges	0	0	0	0	0	0	0	0
Railroad, tracks, and bridges	0	0	0	0	0	0	0	0
Subtotal	2	2	2	2	2	2	2	2
Total, single levee plan	1,247	1,281	1,489	1,712	1,878	2,016	2,089	1,574

Table E-10. Continued

Alternative double levee Land Use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
Damages Prevented from Flooding on the Little Colorado River								
Single family residential								
Conventional								
Structures	196	196	222	244	270	291	304	231
Contents	166	199	285	384	421	454	469	313
Mobile homes								
Structures	7	7	7	8	9	10	10	8
Contents	5	6	6	10	12	12	13	9
Commercial								
Auto repair and sales	32	32	36	38	42	45	48	37
Strip	193	193	217	240	264	283	291	226
Two-story	6	6	6	6	6	6	6	6
Motels	122	122	137	152	167	179	185	142
Restaurants	34	34	38	42	47	50	52	40
Gas stations	22	22	24	27	30	32	34	26
Public								
Office	37	37	37	41	46	50	53	43
Schools	282	282	317	353	388	419	432	332
Industrial								
Warehouses	30	30	34	38	41	46	49	36
Manufacturing	3	3	3	4	4	4	5	4
Semipublic	17	17	19	21	23	25	26	20
Income losses	40	40	46	50	54	57	59	52
Streets, highways, and bridges	3	3	3	3	3	3	3	3
Railroad, tracks, and bridges	63	63	63	63	63	63	63	63
Subtotal	1,258	1,292	1,500	1,724	1,890	2,029	2,102	1,591

Table E-10. Continued.

Land Use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
Damages Prevented from Flooding by Interior Drainage								
Single family residential								
Conventional								
Structures	2	2	2	2	2	2	2	2
Contents	0	0	0	0	0	0	0	0
Mobile homes								
Structures	0	0	0	0	0	0	0	0
Contents	0	0	0	0	0	0	0	0
Commercial								
Auto repair and sales	0	0	0	0	0	0	0	0
Strip	0	0	0	0	0	0	0	0
Two-story	0	0	0	0	0	0	0	0
Motels	0	0	0	0	0	0	0	0
Restaurants	0	0	0	0	0	0	0	0
Gas stations	0	0	0	0	0	0	0	0
Public								
Office	0	0	0	0	0	0	0	0
Schools	0	0	0	0	0	0	0	0
Industrial								
Warehouses	0	0	0	0	0	0	0	0
Manufacturing	0	0	0	0	0	0	0	0
Semipublic	0	0	0	0	0	0	0	0
Income losses	0	0	0	0	0	0	0	0
Streets, highways, and bridges	0	0	0	0	0	0	0	0
Railroad, tracks, and bridges	0	0	0	0	0	0	0	0
Subtotal	2	2	2	2	2	2	2	2
Total, double-levee plan	1,260	1,294	1,502	1,726	1,902	2,031	2,104	1,593

Table E-10. Continued.

Alternative floodproofing

Land Use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
Damages Prevented from Flooding of the Little Colorado River								
Single family residential								
Conventional								
Structures	146	146	166	182	201	217	227	173
Contents	123	148	212	286	314	338	349	232
Mobile homes								
Structures	5	5	5	6	7	8	8	7
Contents	4	5	5	8	9	9	9	7
Commercial								
Auto repair and sales	24	24	27	29	32	34	36	28
Strip	145	145	163	180	198	212	218	170
Two-story	5	5	5	5	5	5	5	5
Motels	92	92	103	114	125	134	159	107
Restaurants	26	26	29	32	35	38	39	30
Gas stations	17	17	18	20	23	24	26	20
Public								
Office	28	28	28	31	35	38	40	33
Schools	212	212	238	265	291	314	324	249
Industrial								
Warehouses	23	23	26	29	31	35	37	27
Manufacturing	2	2	2	2	2	2	3	2
Semipublic	13	13	14	16	17	19	20	15
Income losses	10	10	12	12	13	14	14	12
Streets, highways, and bridges	0	0	0	0	0	0	0	0
Railroad, tracks, and bridges	0	0	0	0	0	0	0	0
Subtotal	875	901	1,053	1,217	1,338	1,441	1,494	1,117

Table E-10. Continued.

Land use	1979	1985	1995	2005	2015	2025	2035-85	Equivalent Annual (7.125%-100 yrs)
	Damages Prevented from Flooding Interior Drainage							
Single family residential								
Conventional								
Structures	22	22	22	22	22	22	22	22
Conventional	5	5	7	9	9	9	9	8
Mobile homes								
Structures	0	0	0	0	0	0	0	0
Contents	0	0	0	0	0	0	0	0
Commercial								
Auto repair and sales	0	0	0	0	0	0	0	0
Strip	2	2	2	2	2	2	2	2
Two-story	0	0	0	0	0	0	0	0
Motels	3	3	3	3	3	3	3	3
Restaurants	0	0	0	0	0	0	0	0
Gas stations	0	0	0	0	0	0	0	0
Public								
Office	2	2	2	2	2	2	2	2
Schools	5	5	5	5	5	5	5	5
Semipublic	0	0	0	0	0	0	0	0
Income losses	0	0	0	0	0	0	0	0
Streets, highways, and bridges	0	0	0	0	0	0	0	0
Railroad, tracks, and bridges	0	0	0	0	0	0	0	0
Subtotal	39	39	41	43	43	43	43	42
Total, floodproofing plan	914	940	1,094	1,260	1,381	1,484	1,537	1,159

Table E-11. Present land use in the Little Colorado River overflow area by flood (units)

Land use	SPF	100-Year	50-Year
Single-family residential			
Conventional	632	600	600
Mobile homes	26	26	26
Commercial			
Auto repair and sales	13	13	13
Strip	75	75	75
Two-story	4	4	4
Motels	18	18	18
Restaurants	12	11	11
Gas stations	14	14	14
Public			
Office	15	15	15
Schools	11	10	10
Semipublic			
Churches	10	10	10
Industrial			
Warehouses	10	10	10
Manufacturing	15	15	15

Table E-12. Present land use in the interior drainage overflow area by discharge (units).

Land use	3,000 cfs	2,000 cfs	1,000 cfs
Single-family residential			
Conventional	431	396	333
Mobile homes	43	12	6
Commercial			
Auto repair and sales	9	9	5
Strip	66	66	38
Two-story	2	2	2
Motels	19	19	12
Restaurants	10	10	8
Gas stations	11	11	8
Public			
Office	9	9	9
Schools	3	3	3
Semipublic			
Churches	12	12	12

Table E-13. Unit values in flood plain by flood and property type - Little Colorado River
(In thousands of dollars.)

Land use	Average value of structures	Average value of contents	Average value of contents as % of structures	Other land uses Average value of structures and contents
STANDARD PROJECT FLOOD				
Single-family residential				
Conventional	15.2	6.3	41.	
Mobile homes	10.5	4.8	46.	
Commercial				
Auto repair and sales				69.5
Strip				80.7
Two-story				95.3
Motels				228.1
Restaurants				89.8
Gas stations				139.6
Public				
Office				77.1
Schools				1,448.3
Semipublic				
Churches				62.0
Industrial				
Warehouses				131.5
Manufacturing				7.8
100-YEAR FLOOD				
Single-family residential				
Conventional	15.2	6.3	41.0	
Mobile homes	10.5	4.8	46	
Commercial				
Auto repair and sales				69.5
Strip				80.9
Two-story				95.3
Motels				228.1
Restaurants				58.8
Gas stations				139.6
Public				
Office				77.1
Schools				813.1
Semipublic				
Churches				62.0
Industrial				
Warehouses				131.5
Manufacturing				7.8

Table E-14. Present and future value of property in Little Colorado River flood plain by land use.
(In thousands of dollars.)

Land use	1979	1985	995	2005	2015	2025	2035-85
STANDARD PROJECT FLOOD							
Single-family residential							
Conventional							
Structures	9,603	9,603	9,603	9,603	9,603	9,603	9,603
Contents	3,991	4,733	6,051	7,257	7,257	7,257	7,257
Mobile homes							
Structures	272	272	2722	272	272	272	272
Contents	124	148	190	205	205	205	205
Commercial							
Auto repair and sales	904	904	904	904	904	904	904
Strip	6,056	6,056	6,056	6,056	6,056	6,056	6,056
Two-story	381	381	381	381	381	381	381
Motels	4,106	4,106	4,106	4,106	4,106	4,106	4,106
Restaurants	1,078	1,078	1,078	1,078	1,078	1,078	1,078
Gas stations	1,954	1,954	1,954	1,954	1,954	1,954	1,954
Public							
Office	1,156	1,156	1,156	1,156	1,156	1,156	1,156
Schools	15,931	15,931	15,931	15,931	15,931	15,931	15,931
Industrial							
Warehouses	1,315	1,315	1,315	1,315	1,315	1,315	1,315
Manufacturing	117	117	117	117	117	117	117
Semipublic	620	620	620	620	620	620	620
Streets, highways, and bridges	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Railroad, tracks, and bridges	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Total	52,608	53,374	54,734	55,955	55,955	55,955	55,955

Table E-14. Continued.

Land Use	1979	1985	1995	2005	2015	2025	2035-85
100-YEAR FLOOD							
Single family residential							
Conventional							
Structures	9,603	9,603	9,603	9,603	9,603	9,603	9,603
Contents	3,991	4,733	6,051	7,257	7,257	7,257	7,257
Mobile homes							
Structures	272	272	272	272	272	272	272
Contents	124	148	190	205	205	205	205
Commercial							
Auto repair and sales	904	904	904	904	904	904	904
Strip	6,056	6,056	6,056	6,056	6,056	6,056	6,056
Two-story	381	381	381	381	381	381	381
Motels	4,106	4,106	4,106	4,106	4,106	4,106	4,106
Restaurants	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Gas stations	1,954	1,954	1,954	1,954	1,954	1,954	1,954
Public							
Office	1,156	1,156	1,156	1,156	1,156	1,156	1,156
Schools	8,131	8,131	8,131	8,131	8,131	8,131	8,131
Industrial							
Warehouses	1,315	1,315	1,315	1,315	1,315	1,315	1,315
Manufacturing	117	117	117	117	117	117	117
Semipublic	620	620	620	620	620	620	620
Streets, highways, and bridges	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Railroad, tracks, and bridges	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Total	48,721	49,487	50,847	52,068	52,068	52,068	52,068

Table E-14. Continued

Land Use	1979	1985	1995	2005	2015	2025	2035-85
50-YEAR FLOOD							
Single-family residential							
Conventional							
Structures	9,194	9,194	9,194	9,194	9,194	9,194	9,194
Contents	3,972	4,714	6,032	7,238	7,238	7,238	7,238
Mobile homes							
Structures	272	272	272	272	272	272	272
Contents	124	148	190	205	205	205	205
Commercial							
Auto repair and sales	904	904	904	904	904	904	904
Strip	6,056	6,056	6,056	6,056	6,056	6,056	6,056
Two-story	381	381	381	381	381	381	381
Motels	4,106	4,106	4,106	4,106	4,106	4,106	4,106
Restaurants	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Gas stations	1,954	1,954	1,954	1,954	1,954	1,954	1,954
Public							
Office	1,156	1,156	1,156	1,156	1,156	1,156	1,156
Schools	8,131	8,131	8,131	8,131	8,131	8,131	8,131
Industrial							
Warehouses	1,094	1,094	1,094	1,094	1,094	1,094	1,094
Manufacturing	54	54	54	54	54	54	54
Semipublic	620	620	620	620	620	620	620
Streets, highways, and bridges	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Railroads, tracks, and bridges	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Total	48,293	49,059	50,419	51,640	51,640	51,640	51,640

Table E-15. Methodology for computing recreational benefits.

Recreational demand in recreational market area

Activity	Recreation market area population	X	Adjusted annual per capita-use-rate in recreation days	=	Total activity potential demand in recreation days	-	Existing formal supply of recreation days	-	Recreation days to be provided by project	=	Net potential demand
Bicycling	6,000	X	*11.7	=	70,200	-	0	-	15,000	=	55,200
Picnicking	6,000	X	*6.7	=	42,200	-	3,750	-	12,500	=	25,750

Recreational supply to be provided by project

Activity	Density	X	Units	X	Turnover	÷	Duplication ratio	X	N/WM	=	Maximum annual recreation days to be provided by project
Bicycling	10/mile	X	3 miles	X	4	÷	1.2	X	150	=	15,200
Picnicking	5/table	X	10 tables	X	2	÷	1.2	X	150	=	12,500

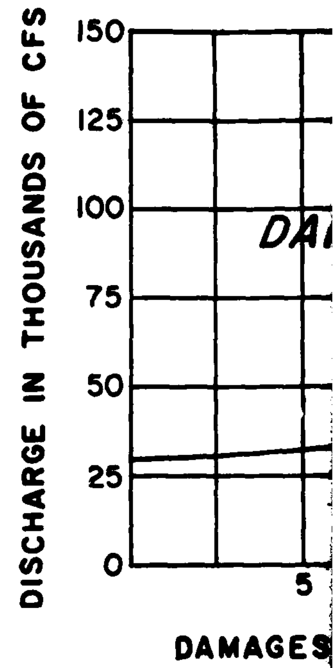
Annual benefits activity	Annual recreation days	X	Benefit unit value	=	Annual benefits
Bicycling	15,000		$1	=	$15,000
Picnicking	12,500		$1	=	$12,500
Total					$27,500

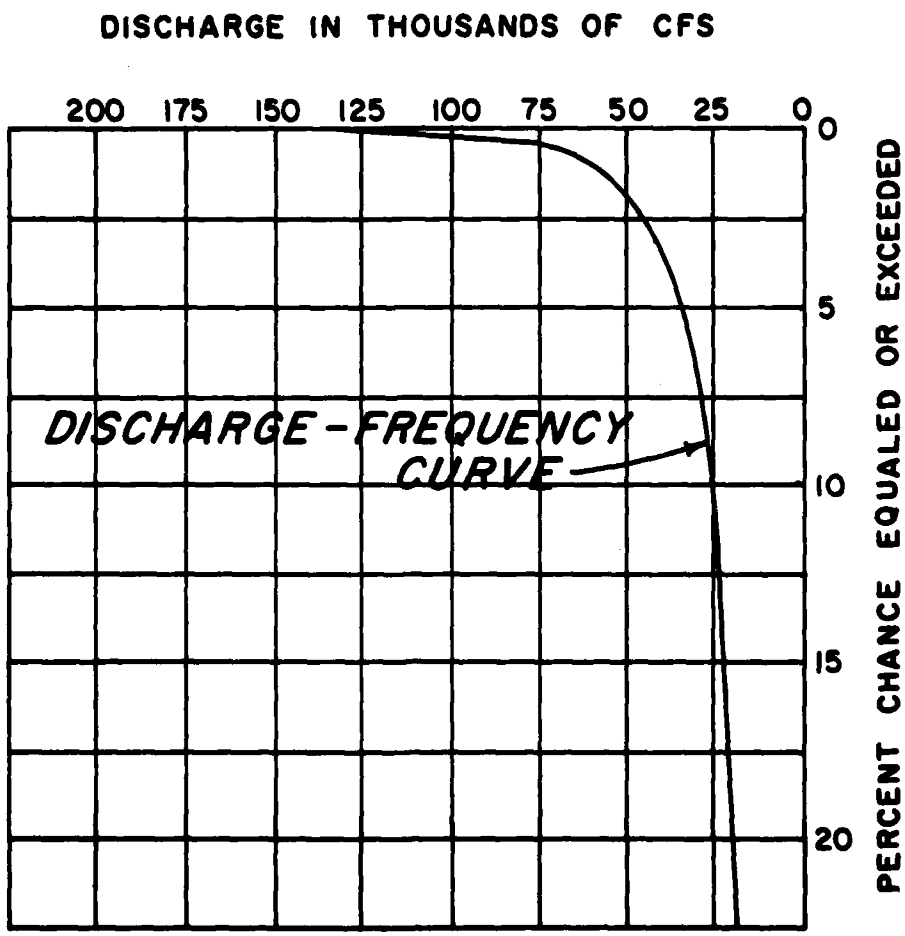
Equivalent annual benefits

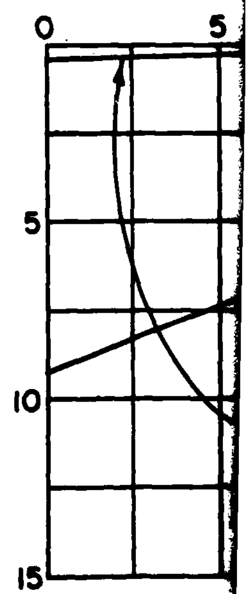
1/2 Maximum benefits bicycling ($15,000/2)	$ 7,500
1/2 Maximum benefits picnicking ($12,500/2)	$ 6,125
1/2 Maximum benefits bicycling X capital recovery factor at maximization (0.847596 X $7,500)	$ 6,357
1/2 Maximum benefits picnicking X Capital recovery factor at maximization (0.847596 X $6,125)	$ 5,192
Total equivalent annual benefits	$25,174
say	$25,000

*"State of Arizona Statewide Comprehensive Recreation Plan," per-capita demand for Navajo County.

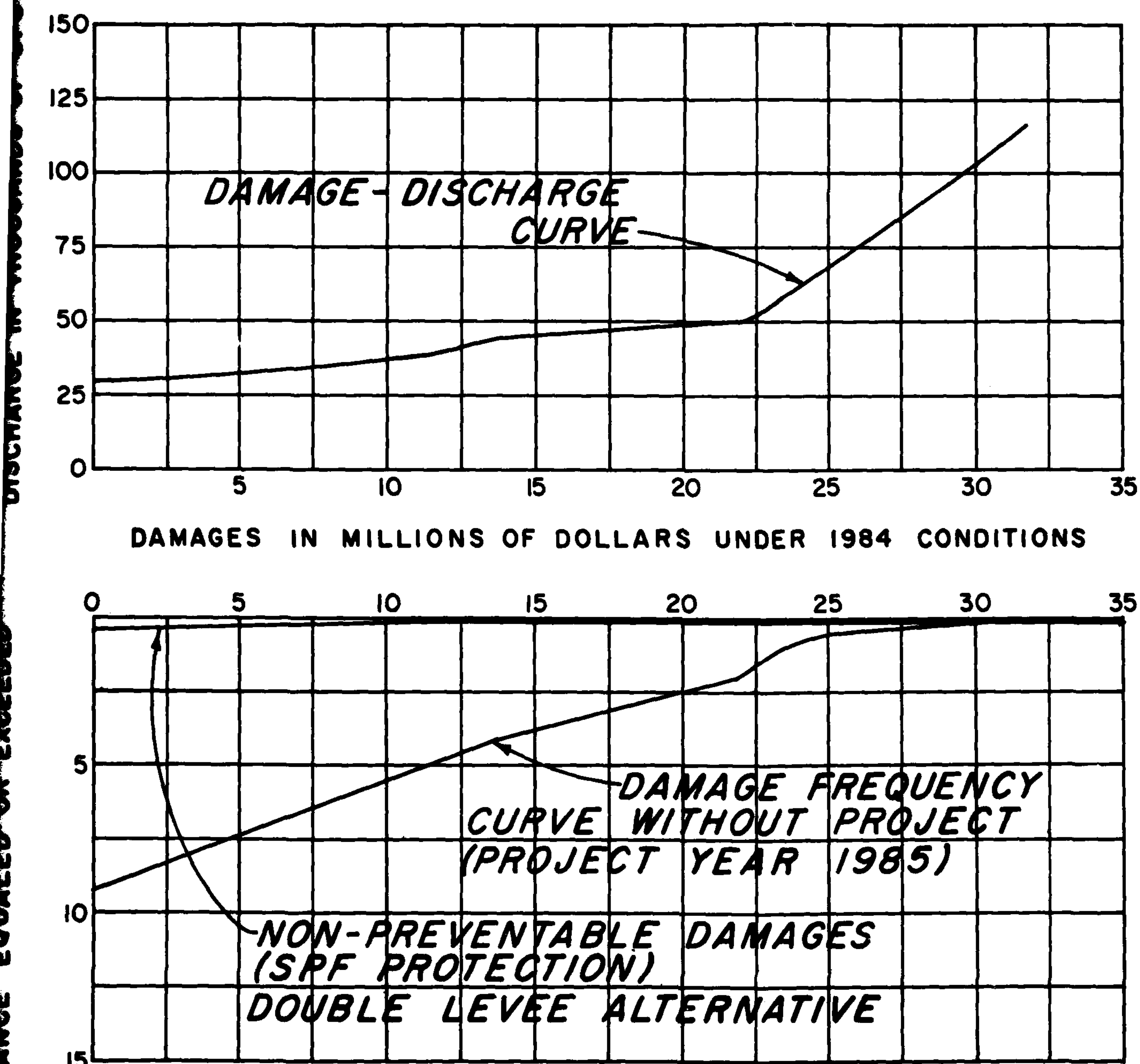
U. S. ARMY ENGINEER DISTRICT







CORPS OF ENGINEERS



LITTLE COLORADO RIVER
AT HOLBROOK, ARIZONA

REVIEW REPORT FOR FLOOD CONTROL
AND RECREATIONAL DEVELOPMENT

DAMAGE-DISCHARGE
FREQUENCY RELATIONSHIP

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

FIGURE E-1

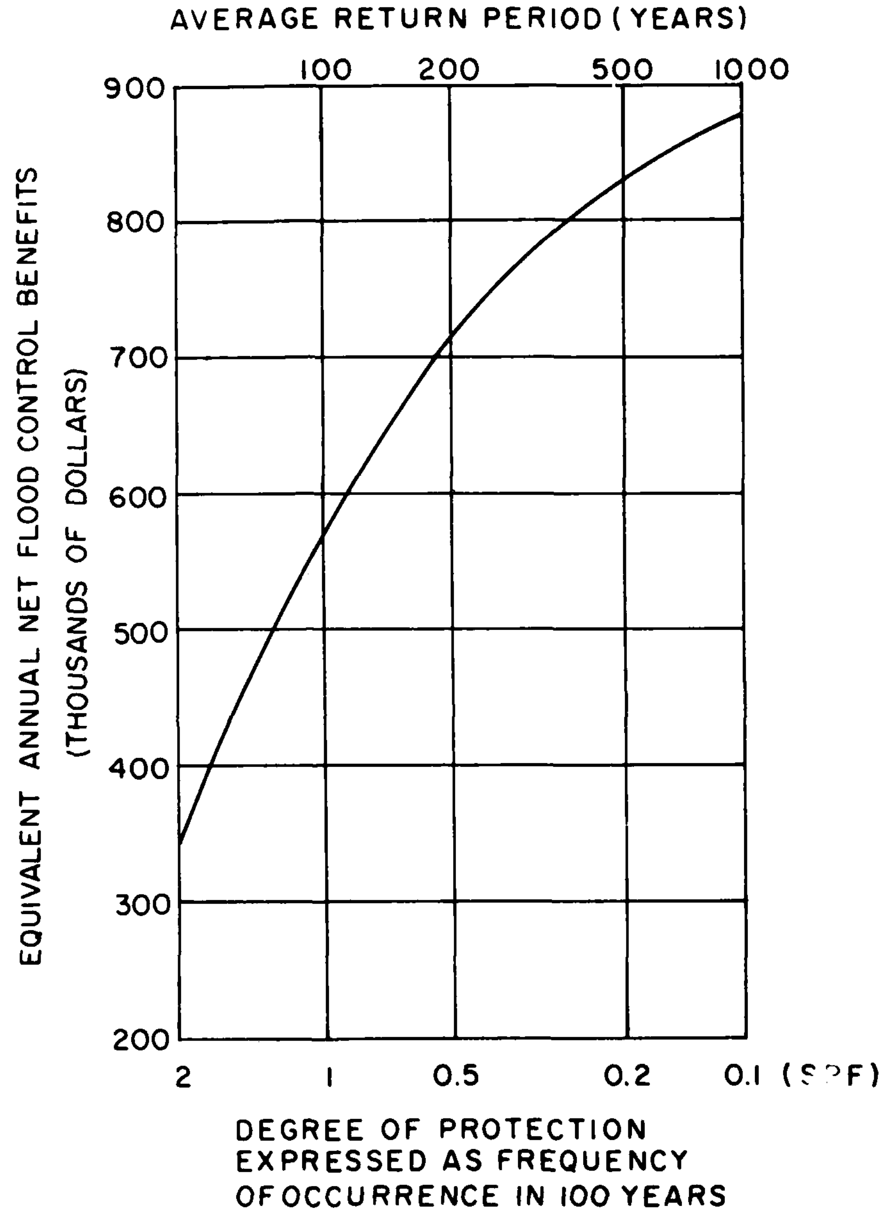


FIGURE E-2 MAXIMIZATION OF NET FLOOD CONTROL BENEFITS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

Section F

HYDROLOGY

CONTENTS

CONTENTS (Continued)

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Tables

Plates

Section F

HYDROLOGY

INTRODUCTION

Scope

1. This section describes the study made to determine the magnitude of the standard project and intermediate regional floods on the Little Colorado River at Holbrook, Arizona.

Previous Reports

2. Hydrology for the Little Colorado River Basin at Holbrook has been published in two reports by the Corps of Engineers. The earliest data concerned with Holbrook was presented in the report titled "Report on Survey, Flood Control, Little Colorado River and its Tributaries upstream from the boundary of the Navajo Indian Reservation in Arizona," dated December 5, 1940. Additional hdyrology can be found in the "Definite Project Report on the Colorado River Basin, Little Colorado River Levee, Holbrook, Arizona," dated August 1946.

Existing Water-Related Structures

3. Two dams--Zion Dam and Lyman Dam--are present on the Little Colorado River upstream from Holbrook. Zion Dam was almost completed in 1905, but was destroyed by a flood before it could be finished. It was rebuilt in 1908. The reservoir had a capacity of about 13,000 acre-feet, but silting had reduced the capacity to 760 acre-feet. Continued silting has rendered the reservoir unusable. Lyman Dam, about 20 miles upstream from Zion Dam, was destroyed in 1915 and rebuilt in 1920. The reservoir, with its present capacity of 32,200 acre-feet, controls a drainage area of about 790 square miles. Both Zion and Lyman Dams have very little effect on flood peaks at Holbrook because of the large drainage areas that contribute to the main stem below them.

4. Many of the tributaries of the Little Colorado River contain numerous smaller dams (less than 1,000 acre-feet) that are used for irrigation or watersupply.

5. The levee southeast and south of Holbrook was completed in December 1948. Since its construction the river bed has been aggrading, and is now at a point where a serious flood threat exists.

GENERAL DESCRIPTION OF DRAINAGE AREA

Physiographic Characteristics

6. The Little Colorado River and its tributaries have a drainage area of approximately 11,300 square miles at Holbrook, Arizona,

including 1,030 square miles of closed basins. (For location and boundary of the drainage basin, see pl. F-1.) The river originates south of Springerville, Arizona, in the White Mountains, and flows northward to Saint Johns, then in a north-western direction to its confluence with the Puerco River upstream from Holbrook. The river and its tributaries generally are intermittent and flow only after precipitation within their drainage basins. The only perennial water contributing to the drainage system comes from springs issuing from lava beds in Coyote Creek. In contrast, a few areas of interior drainage occur in the lava capped plateaus of the easternmost portion of the basin. The largest area surrounds the region near Quemado, New Mexico, and is approximately 830 square miles in extent; another large area is around the town of El Moro, New Mexico, and is about 200 square miles in extent. Many smaller areas occur in isolated localities, but their size is insignificant when compared with the two largest areas.

7. Elevations within the drainage area range from 11,500 feet above mean sea level at Mount Baldy, southwest of Springerville, Arizona, to just under 5,100 feet at Holbrook. The Little Colorado River has a total length of approximately 320 miles, of which 120 miles are upstream from Holbrook. The streambed slope, which averages 26 feet per mile, varies from a maximum of over 270 feet per mile near the headwaters to a minimum of 3 feet per mile near Holbrook.

8. The region comprising the drainage basin of the Little Colorado River upstream from Holbrook includes part of the Colorado Plateau's physiographic province. This portion of the province is characterized by the nearly horizontal rock formations, the high altitude of the land, and broad valleys with extensive flat, mesa-like highlands. The southern boundary, known as the Mogollon Rim, is characterized by lava-capped mesas, cinder cones, and high volcanic peaks, soils of the drainage area are closely related to the geology and topography. On the high volcanic mountains and lava plateaus are covers of heavy, tight soils, that are fertile, but thin. The transition from the lava fields and mountainous areas to the lower elevation desert-like region around Holbrook is marked by a transition in the soils. In the higher portions, below the peaks, gravelly, sandy soils predominate, changing to sandy loams, loams, and then clays near the flood plains.

9. Vegetal cover of the drainage basin ranges from almost barren desert to mountain forest. In the highest portions of the mountains grow stands of fir and pine; these gradually change to pinion and juniper at lower elevations. The lower open areas are predominantly sagebrush and grasses with a few places essentially barren of any vegetation. The channels support large stands of salt cedar, annual grasses, and shrubs.

Climatology

10. The predominant factor governing the climate of the Little Colorado River drainage basin is topography. The average temperature normally decreases with elevation, while precipitation generally

increases with elevation. The relative humidities in the basin are generally quite low, with some very low values occurring during the warm afternoons of late spring and early summer. The percentage of total possible sunshine is very high, especially in the valley areas.

Temperature

11. The Little Colorado River drainage basin is generally quite warm in summer and relatively mild in winter for this latitude, elevation, and type of terrain. The monthly and annual means, plus recorded extremes of temperature for two selected stations in the basin, are included in table F-1. The normal diurnal temperature variations are quite large (25-40°F) over most of the basin throughout the year, although these diurnal variations, as well as the average temperatures, are somewhat lower over the higher mountain ridges. The highest maximum temperatures in the basin--approximately 110°F-- are found in the lowest valleys, usually in areas of limited vegetation. The lowest minimum temperatures—approximately -35°F--normally occur in sheltered snow-covered valleys at high elevations.

Wind

12. Prevailing winds are normally light through most of the year, reaching monthly averages of around 10 knots during the late spring. The predominant directions are from the southwest in spring and summer, and from the east or southeast during fall and winter.

Precipitation

13. Most of the Little Colorado River drainage basin is arid to semiarid, although some of the higher mountains along the southern edge of the basin receive substantial precipitation. The isohyets of normal annual precipitation (pl. F-2) range from less than 8 inches near Holbrook to more than 40 inches at the top of 11,590-foot Baldy Peak in the southern part of the drainage area.

14. The primary rainy season in this region is summer, although there is a strong secondary season during the winter months. The seasonal distribution of precipitation varies with longitude and elevation, with a decided increase in the comparative importance of winter precipitation toward the west and with increasing elevation. Late spring is the driest time of the year throughout the basin, with only 5 to 10 percent of the year's total precipitation normally falling during the months of May and June combined. There is normally quite a sudden onset of the summer rainy season around the end of June; and at a number of stations June is the year's driest month, and July the wettest. The summer rain regime normally lasts into September, then gradually dies out as it gives way to winter-type rain, which is normally heaviest from December through March. A large percentage of the winter precipitation falls as snow, especially over the higher elevations.

15. The seasonal distribution of precipitation at two stations in the Little Colorado River drainage basin above Winslow, along with the maximum monthly and annual precipitation of record, can be found in table F-1.

Table F-1. Seasonal distribution at selected stations.

Month	Temperature (°F) (Period of record 1886-1973)* Mean monthly	Record highest	Record lowest	Precipitation (in.) (Period of record 1886-1973)* Mean monthly	Record highest	Record lowest
a. Summary of climatological data at Holbrook, Arizona, No. 4089; latitude 34°54' N, longitude 110°10'W, elevation: 5,080 feet.						
January	32.8	73	-20	0.52	2.46	0.00
February	39.2	81	-19	0.55	2.98	0.00
March	45.6	89	6	0.52	2.93	0.00
April	53.4	92	10	0.47	1.84	0.00
May	61.2	101	13	0.29	2.24	0.00
June	70.4	106	31	0.37	3.40	0.00
July	76.7	106	42	1.43	7.09	0.00
August	75.0	109	36	1.49	4.70	0.20
September	67.9	106	18	0.96	3.66	0.00
October	55.8	95	15	0.67	3.44	0.00
November	43.2	89	-10	0.54	3.82	0.00
December	34.0	74	-20	0.57	2.32	0.00
Annual	34.0	109	-20	8.38	17.63	2.60
b. Summary of climatological data at Zuni, FAA AP. N.M., No. 9897; latitude 35°06'N, longitude 108°47'W, elevation 6,440 feet.						
	(Period of record 1908-1973)*			(Period of record 1908-1973)*		
January	29.9	67	-26	0.85	3.40	0.05
February	34.7	72	-20	0.77	2.36	0.02
March	40.4	78	-10	0.85	3.01	T
April	47.9	87	10	0.63	2.15	T
May	56.2	92	20	0.49	2.18	0
June	65.4	100	30	0.54	2.90	0
July	71.1	101	40	2.00	6.25	0.35
August	69.2	97	38	1.88	5.53	0.02
September	62.9	95	26	1.33	3.64	0
October	52.1	85	11	1.32	6.65	0
November	39.7	78	-23	0.71	2.97	0
December	31.5	70	-21	0.88	2.72	0.01
Annual	50.1	101	-26	12.25	19.53	4.41

*Obtained from U.S. Department of Commerce, National Oceanic and Atmospheric Administration, climatological data publications.

Types of Storms

16. There are three basic types of storms that affect the Little Colorado River Basin and surrounding areas: general winter, general summer, and local.

a. General winter storms originate over the Pacific Ocean and move inland across the western United States, spreading general rainfall of light to moderate intensity over large areas, often with snow at the higher elevations. These storms, which affect the southwestern United States mainly from late October through April, reflect orographic influences to a great degree.

b. General summer storms result from a flow of moist tropical air into the region from the southeast or south, and are quite often associated with tropical storms or hurricanes. These general summer storms, which can occur from late June through early October, usually consist of numerous local heavy storms superimposed upon some lighter and more widespread general rain. Some of the late September and October general storms can show characteristics of both the summer and winter types.

c. Local storms—usually thunderstorms—are normally of limited duration and areal extent, but may contain rainfall intensities of several inches per hour. Although these storms can occur at virtually any time of the year, the majority of these storms, and the storms with the greatest potential for cloudburst intensities, occur during the summer and early fall months.

17. The effects of orography upon general summer storms and especially local summer storms are significantly less than upon winter storms, and this results in the larger comparative importance of winter precipitation at the higher elevations, as discussed previously in this section.

Runoff Characteristics

18. Because climatic and drainage area characteristics are not conducive to continuous runoff, little streamflow occurs except during and immediately following intense rainfall, and during period of snowmelt. The streamflow, when it occurs from rainfall, is of the flash-flood type where a dry wash may become a torrent in a matter of minutes. Typically these flows have sharp peaks and are of short duration.

PRECIPITATION AND RUNOFF

Precipitation Records

19. A list of 15 active precipitation stations in and near the Little Colorado River drainage basin above Winslow, along with the latitude, longitudes, and elevations of these stations, can be found in

table F-2. Most of the stations listed in this table are equipped with a regulation 8-inch standard rain gage. Four of these stations have both an 8-inch standard and a recording rain gage. Although the precipitation stations listed in this table have been in operation for more than 30 years, and several date back to around 1890, or even earlier. Several of the regular recording rain gages were put in operation in 1940, and some very limited recording data are available for earlier years. Both the number and the reliability of precipitation records—recording and nonrecording—have increased over the years.

Table F-2. Selected precipitation stations.

Station	Index number	Type	Elevation	Latitude	Longitude	Length of precipitation record
ARIZONA:						
Alpine	0159	NR	8050'	33°51'	109°08'	47 yrs
Ganado	3303	NR	6340'	35°43'	109°34'	43 yrs
Holbrook	4089	NR	5080'	34°54'	110°10'	79 yrs
Keams Canyon	4586	NR&NR	6205'	35°49'	110°12'	37 yrs
McNary	5412	NR	7320'	34°04'	109°51'	37 yrs
Petrified Forest NP	6468	NR&R	5252'	34°48'	109°54'	44 yrs
Sanders	7488	NR	5836'	75°13'	109°20'	10 yrs
Show Low	7855	NR	6400'	34°15'	110°02'	10 yrs
Snowflake	8012	NR	5642'	34°30'	110°05'	65 yrs
Springerville	8162	NR	7060'	34°08'	109°17'	60 yrs
Winslow WSO AP	9439	NR&R	4895'	35°01'	110°44'	63 yrs
NEW MEXICO						
Gallup	3420	NR	6600'	35°32'	108°39'	26 yrs
Grants airport	3682	NR	6520'	35°10'	107°54'	21 yrs
Quemado ranger sta	7180	NR	6879'	34°21'	108°30'	37 yrs
Zuni 4 NE	9897	NR&R	6450'	35°06'	108°06'	61 yrs

R = Recording
NR = Nonrecording

Runoff Records

20. Runoff records are available for 8 U.S. Geological Survey recording stream-gaging stations within the vicinity of Holbrook. Six of the stations are on the Little Colorado River and the other two on major tributaries, the Puerco River and Silver Creek. Three of the gages on the Little Colorado River are downstream from Holbrook, and two of these are so far distant that they are not very representative of flows from the study area. The third gage (located 5 miles west of Holbrook) was established in July 1973 and its record is too short for a frequency analysis but can be used as a guide in estimating peak flows that have occurred at Holbrook. The Holbrook gage was discontinued in 1974 because its control section is unstable. The location of all the gages is shown on plate F-1 and pertinent data for each gage is listed in table F-3. The recorded peak flows for the Little Colorado River at Holbrook is listed in table F-4. Plate F-3 shows a graphic representation of the length of record.

Table F-3. Stream-gaging stations.

Gage number (U.S.G.S no.)	Location	Drainage area (Sq. miles)	Period of Record (No. of yrs)	Peak discharge (cfs)
09402000	Little Colorado River near Cameron, AZ	26,500 (Apx)	28	24,900
09401000	Little Colorado River at Grand Falls, AZ	21,200 (Apx)	35	50,500
09397300	Little Colorado River near Joseph City, AZ	12,200 (Apx)	3	20,600
09397000	Little Colorado River at Holbrook, AZ	11,300 (Apx)	24	24,200
09395500	Puerco River at Gallup, New Mexico	558	24	12,000
09394500	Little Colorado River at Woodruff, AZ	8,100 (Apx)	45	25,000
09393500	Silver Creek near Snowflake, AZ	886	23	10,100
09388000	Little Colorado River near Hunt, AZ	6,280 (Apx)	38	8,000
09386500	Little Colorado River above Zuni River	3,680 (Apx)	33	1,100
09384000	Little Colorado River above Lyman Reservoir	747	34	16,000

Table F-4. Annual peak flows, Little Colorado River at Holbrook, No. 093970000

Water year	Date	Peak
1950	July 19, 1950	2,960
1951	August 28, 1951	8,700
1952	January 19, 1952	8,400
1953	July 29, 1953	6,030
1954	July 22, 1954	10,800
1955	August 17, 1955	10,500
1956	June 30, 1956	4,210
1957	August 5, 1957	21,800
1958	September 14, 1958	7,000
1959	August 5, 1959	6,300
1960	October 29, 1960	11,400
1961	August 16, 1961	4,160
1962	October 31, 1962	4,010
1963	August 31, 1963	9,370
1964	September 9, 1964	15,100
1965	July 25, 1965	14,800
1966	August 13, 1966	10,400
1967	August 12, 1967	14,100
1968	August 12, 1968	21,000
1969	October 4, 1968	24,200
1970	September 5, 1970	19,700
1971	August 12, 1971	13,200
1972	October 1, 1971	20,300
1973	October 20, 1972	15,000
1974*	July 22, 1974	3,880
1975	October 29, 1974	20,600
1976	July 30, 1976	3,880
1977	August 18, 1977	12,000
1978	March 1, 1978	5,200
1979	December 19, 1978	25,000

*Note: Data from gage 09397000 discontinued in 1974. Data for 1974 through 1979 for the Little Colorado River at Joseph City, U.S.G.S Gage No. 09397300.

Storms and Floods of Record

21. The larger floods on the main river and the major tributaries result mostly from general storms, usually general winter storms. Floods on the smaller tributaries or near the headwaters of the larger streams are caused mostly by local storms, usually during the summer season, and are often of the flash flood variety. Because of the size of the overall drainage basin and the large number of small tributary streams, the occurrence of a local flash flood somewhere in the basin is not an uncommon event during the summer season.

Historical Storms and Floods

22. Quantitative measurements of early floods on the Little Colorado River (prior to 1950) are meager, but sketchy accounts of several of the larger events are available from the U.S. Geological Survey, the U.S. Weather Bureau, the U.S. Bureau of Reclamation, and local interests, including newspaper files. Regular streamflow measurements on the Little Colorado River have been made by the U.S. Geological Survey in recent years. Flood hydrographs from past recorded events are shown on plates F-4, F-5, F-6, F-7, and F-8. The flood event of August 10-12, 1968, as recorded by the Holbrook and Woodruff gages is shown on plate F-4. The flood hydrographs for the flood of October 3-5, 1968, as recorded by the gages at Holbrook, Hunt, and Woodruff, are shown on plate F-6. The flood event of September 30 to October 2, 1971, as recorded by Holbrook, Hunt, and Woodruff gages, is shown on plate F-7. The Hunt gage was discontinued in Septemer 1972; hence plate F-8 shows only the Holbrook and Woodruff gage flood hydrographs for the October 20, 1972, event. A listing of annual peak floodflows on the Little Colorado River at Holbrook is shown in table F-4.

23. The greatest flood peak for which data is available on the Little Colorado River at Holbrook was estimated to be 60,000 cfs in September 1923.

24. All the historical storms and floods that have occurred in the Little Colorado River Basin are discussed in the following paragraphs, including some unusually heavy storms that have occurred outside the basin, but are significant to a hydrologic investigation of the Little Colorado River because of the possibility of occurrence of similar storms over the basin.

a. **FLOODS PRIOR TO 1900.** Very little is known about the floods in this region prior to 1900. There are accounts of major floods that occurred on the Gila River system and other Arizona watersheds in 1833, 1862, 1869, 1880, 1884, and 1891. The storm of February 1891 covered a very large portion of the southwestern United States, and the resulting flood on the lower Gila River was especially destructive.

b. **STORM AND FLOOD OF NOVEMBER 25-28, 1905.** The year 1905 was very wet over the southwestern United States (the wettest that has ever been recorded at Holbrook and several other stations), and a number of

significant floods occurred during the first several months of the year. The floods of late November 1905, however, were in general the most severe since at least 1891. A protracted period of light precipitation during the early part of the month and a fairly heavy storm from November 21 to 23 added considerable moisture to the soil and provided a moderate snow cover. This was followed by the major storm that moved in from the northwest on the 25th and 26th and intensified over the region. Precipitation intensities were apparently high, although quantitative measurements of short duration amounts are not available. This heavy rainfall, combined with the low loss rates resulting from the antecedent moisture, plus the melting of a considerable portion of the snow on the ground, caused very severe floods on the Little Colorado River and other streams.

c. STORM AND FLOOD OF DECEMBER 13-17, 1908. This was a general winter storm with widespread precipitation over northeastern Arizona. Flooding was quite severe; notably on the Little Colorado River at Holbrook.

d. STORM OF OCTOBER 5-6, 1911. A tropical storm from the west coast of Mexico and a cold front from the Pacific combined over northwestern Arizona to furnish precipitation over the Little Colorado River Basin. Heaviest rain was centered in southwest Colorado.

e. STORMS AND FLOODS OF JANUARY 1916. Throughout January 1916 an extraordinary series of intense Pacific winter storms moved southeastward across the southwestern United States, with a number of storm centers passing directly over central Arizona. The two most significant storm periods were January 15-21, and January 25-30, with the former period generally accounting for the heavier precipitation amounts in Arizona and western New Mexico. Flooding during the month was widespread and severe on nearly every major river and stream in the southwestern United States. Conditions conducive to flooding had begun in December 1915, when a series of storms deposited a heavy snow cover over the mountains of Arizona and New Mexico. After some warming in early January 1916, some light general rain between the 10th and the 12th added to the moisture content of the snow and the soil. Thus the snowpack was ripe and the infiltration rates were low as the mid-January series of warm rain storms began. Total rainfall between January 15 and 21, 1916, ranged from just over 1 inch in the region north of Winslow to as much as 5.5 inches in the higher mountains along the southern edge of the drainage basin (and up to 9.1 inches in the mountains just northeast of Phoenix). Maximum recorded daily amounts of rain in the little Colorado River Basin ran as high as 1.70 inches. The floods that resulted from these storms were among the most severe on record, and in several instances were the greatest to date since 1891. No quantitative measurements of flood peaks were available on the Little Colorado River, but accounts indicate that the entire basin experienced severe flooding.

f. STORM AND FLOOD OF SEPTEMBER 13-18, 1923. The storm period of mid-September 1923 consisted of a series of individual storms that dropped rapidly southward from out of Canada and intensified over the

far southwestern United States. Although there was undoubtedly a considerable amount of tropical moisture in these storms, their general appearance seems to have been more characteristic of general winter storms than of general summer storms. The heaviest precipitation fell generally on September 17 and 18, with large 24-hour maxima occurring simultaneously over the entire Little Colorado River drainage basin. This helped to contribute to an estimated peak flood of 60,000 cfs on the Little Colorado River at Holbrook and 120,000 cfs at Grand Falls (some distance downstream from Winslow)--the greatest known values in the river's history at these respective locations.

g. STORMS AND FLOODS, 1924-1941. There were a number of notable flood-producing storms that hit central and northeastern Arizona during this period, especially in 1929, 1937, 1938, 1940, and 1941. Various tributaries to the Little Colorado River, the Gila River, and others experienced significant flooding from one or more of these events. However, the floods on the Little Colorado River at and above Holbrook were generally of lower magnitude than those of other historical periods.

h. STORM OF OCTOBER 27-29, 1946. A Pacific storm deepened over the Great Basin region and developed very heavy precipitation over southwest Utah and Western Nevada.

i. STORM AND FLOODING OF AUGUST 23-26, 1951. A Pacific tropical storm and a hurricane from the Gulf of Mexico combined and moved northeastward into the Colorado River Valley. Rainfall was heaviest in the mountains of central Arizona, with more than 13.5 inches reported at Crown King, and nearly 9 inches along the Mogollon Rim. Flooding occurred on a number of tributaries to the Salt and Gila Rivers.

j. STORM OF AUGUST 19, 1954. The intense thunderstorm that occurred over the Queen Creek drainage area of central Arizona was the most severe for the region and perhaps the largest and heaviest local storm with reasonably good documentation in the history of the State. Amounts of up to 5.3 inches were reported, with one station measuring 4.05 inches in less than 2 hours.

k. STORM AND FLOOD OF AUGUST 9-12, 1968. Showers and thunderstorms prevailed throughout northeastern Arizona during the first half of August 1958, as a moist flow of tropical air from the south continued to invade the region. This was climaxed between August 9 and 12, as the moist flow increased and picked up some outflow from two distant tropical storms. Precipitation over the Little Colorado River Basin during the period ranged from around one-third of an inch in the central and northern portions of the basin to around 2 inches in the higher mountains forming the southern boundary of the drainage. The peak flow on the Little Colorado River at Holbrook was 21,000 cfs on 12 August.

l. STORM AND FLOOD OF OCTOBER 3-5, 1968. An upper-level low-pressure center off the southern California coast pumped large

quantities of tropical moisture into Arizona during the first few days of October 1968. On October 2 Hurricane Pauline crossed the Baja California peninsula and the Gulf of California, dissipating over Sonora, Mexico. The remnants of this tropical cyclone were picked up by the circulation around this upper level low and directed into eastern Arizona. This resulted in numerous showers and thunderstorms over the Little Colorado river drainage basin from midday on October 3 into the morning of October 4. Precipitation amounts were irregular, with total storm depths varying from 0.18 at Springerville to 2.27 inches at Lakeside Ranger Station, about 40 miles away. Most stations within the basin reported 0.50 to 1.50 inches. The peak flow on the Little Colorado River at Holbrook was 24,200 cfs on October 4.

m. STORM AND FLOODS OF SEPTEMBER 3-7, 1970. As moisture streaming northward from Tropical Storm Norma and the warm ocean area off Baja California spread across Arizona, an intensifying lower pressure system with a strong cold front moved into the region from the northwest and collided with this tropical moisture, setting off extremely heavy rains in central Arizona, especially in the mountain areas where orographic lifting of strong southernly winds considerably enhanced the precipitation rates. Numerous rainfall stations recorded 5 to 8 inches within 24 hours; and Workman Creek, located in the mountains about 60 miles northeast of Phoenix, measured 11.4 inches in 24 hours for a new all-time State of Arizona record. Flooding was widespread, especially on creeks and streams draining southward from the central Arizona mountains. Rainfall over the Little Colorado River Basin was only moderate in this storm, except for one isolated report of 6.50 inches on September 6 at the Seba Dalkai School northwest of Holbrook--undoubtedly caused by a local thunderstorm. A peak discharge of 19,700 cfs was recorded on September 6 at the Holbrook gage on the Little Colorado River.

n. STORM AND FLOOD OF SEPTEMBER 29-OCTOBER 2, 1971. A deep upper level low dropping southeastward from the Pacific Northwest triggered widespread shower activity over northeast Arizona on September 29 and 30, 1971. Moisture was augmented by outflow from Tropical Storm Olivia moving northeastward across central Baja California. On October 1, a cold front and the upper level low passed across the region, followed by cooler and drier air. Precipitation over the Little Colorado River basin during this 3-day storm period was generally 1 to 2 inches, but amounts up to 4 inches fell in the mountains to the south. The peak flow on the Little Colorado River at Holbrook was 20,300 cfs on October 1.

o. STORM AND FLOOD OF OCTOBER 16-20, 1972. A deep upper level cold low developed off the coast of California during mid-October and pumped large quantities of tropical moisture into Arizona and New Mexico from October 16 to 20, causing widespread moderate to heavy shower activity throughout the region. Precipitation over the Little Colorado River Basin generally ranged from 2 to 3 inches through the storm period, but a few amounts of greater than 5 inches were recorded in some

mountain areas in the extreme southern part of the drainage. The peak flow on the Little Colorado River at Holbrook was 15,000 cfs on October 20.

p. Flood of 9 September 1975. The peak discharge of the 9 September 1975 flood at Joseph City was 20,600 cfs. The peak flow at Holbrook was probably approximately the same. No damage resulted in the Little Colorado River Basin from this flood.

q. STORM AND FLOOD OF 16-20 DECEMBER 1978. Widespread, heavy rain during the period from December 16-20, 1978 resulted in extensive and record-breaking floods throughout much of Arizona. The heavy precipitation that caused the flooding resulted from a large amplitude trough over the eastern Pacific, advecting tropical moisture over the southwestern U.S. as it lingered over the eastern Pacific from December 16 through December 20. Except for the extreme northern and western parts of the state, rainfall amounts generally were in excess of 2 inches, with higher elevations receiving 4-6 inches or more in the Little Colorado River Basin, frozen ground contributed significantly to runoff. Floodwaters moving down the Little Coloraado River from Show Low, Snowflake and Taylor did not cause any damage in Holbrook, although the river crested approximately one foot below the girders of the U.S. 180 bridge. The estimated peak discharge at Holbrook was about 25,000 cfs occurring on 19 December.

SYNTHESIS OF STANDARD PROJECT FLOOD

General

25. The standard project flood for the Little Colorado River at Holbrook was developed according to criteria given in EM 1110-2-1411, Standard Project Flood Determinations.

Determination of Standard Project Storm

26. The standard project storm for the study area was determined by evaluating several storms that occurred near and in the drainage basin.

Standard Project Storm

27. The general summer storm of September 4-6, 1970 (pl. F-9), was determined to be the critical standard project storm for the Little Colorado River Basin above Holbrook. The "Labor Day" storm, which centered in the mountains of central Arizona, resulted from the collision of warm, moist tropical air with a strong cold front, and the rapid lifting of this moist air by the mountain ridges. The depth-area-duration pattern of precipitation is considered to be the most severe that may reasonably be expected to occur in this portion of the State.

28. The standard project storm was transposed and centered over the area tributary to the Little Colorado River at Holbrook by using isopercentuals of 2-year, 24-hour precipitation. Isopercentuals of the September 1970 storm as centered for Holbrook are shown on plate F-10. Although the area of maximum isopercentuals occurred in the desert west of Phoenix, the portion actually transposed occurred in the mountains midway between Phoenix and Holbrook. The isopercentuals were superimposed over the Little Colorado River Basin in such a way as to result in the greatest storm precipitation depths that would be consistent with rainfall amounts indicated by the 2-year, 24-hour precipitation (pl. F-11). It was felt that transposition was reasonable because of the general similarity of climate and elevation between the location of the original storm and the Holbrook drainage basin. The time distribution of precipitation used for the study was based upon the average of time distributions during the September 1970 storm of three recording rain gages located within the (original) storm area. A time interval of 1/2 hour was selected as the shortest time interval for which precipitation intensities would be required to define accurate flood hydrographs.

Precipitation-Runoff Relationships

29. The lack of adequate precipitation-runoff data for the drainage basin precludes any attempt at reconstitutions of flood events. The methods used for this study were based generally on those used in other comparable streams in central and northern Arizona.

a. UNIT HYDROGRAPHS. The method used to develop synthetic unit hydrographs is the Los Angeles Hydrograph procedure as described in TB 5-550-3, "Flood Prediction Techniques," dated February 1957. Unit hydrographs were developed for the subareas using the lag-relationship curve (pl. F-12) and the Phoenix Mountain S-graph (pl. F-13). Basin "N" values for each subarea ranged from 0.035 to 0.045, and were determined from field inspection and judgment. Pertinent data for the various subareas are given in table F-5.

Table F-5. Drainage basin subarea characteristics.

Subarea Designation	Drainage area (Square miles)	L (Miles)	LCA (Miles)	Slope (Ft/mile)	"N"-value
A	*2,200	69.4	32.3	42	0.045
B	1,330	64.6	32.3	70	0.045
C	**2,730	96.6	52.7	31	0.045
D	820	59.9	32.3	70	0.040
E	1,008	53.5	27.9	37	0.045
F	170	31.1	14.4	26	0.035
G	3,030	131.7	68.6	23	0.040

* Total drainage area; 1,370 sq. miles contributing, 830 sq. miles closed basin.

** Total drainage area; 2,530 sq. miles contributing, 200 sq. miles closed basin.

b. PRECIPITATION-LOSS RATES. Precipitation-loss rates cannot be accurately determined for the study area because of inadequate runoff data. However, rates have been determined for areas of similar physical characteristics. The loss rates for the general storm were determined using the HEC loss rate program with a STRKR = 0.30, DLTKR = 0, and RTIOL = 2.00. Because of the large size of the basin, imperviousness is considered negligible.

c. PERCOLATION AND BASEFLOW. Percolation and baseflow were considered to be negligible for all the subareas in the drainage basin.

d. SNOWMELT. Snowmelt is not considered to be a significant contributing factor to the peak of the standard project flood. The generally high elevation of most of the drainage basin is not conducive to rapid snowmelt and the production of a flood of the type and magnitude of the standard project flood. Snowmelt for long periods would produce a flood of record volume, but not generally with a high peak.

Determination of the Standard Project Flood

30. The standard project flood was determined by the following procedure:

a. Determination of unit-time increments of precipitation for each sub-area.

b. Determination of effective precipitation by subtraction of loss rates.

c. Determination of subarea surface-runoff hydrograph by application of subarea synthetic unit-hydrograph values to the effective unit-period precipitation.

d. Determination of the total flood hydrograph by channel routing and combining subarea hydrographs as required.

31. The routing of the peak flows from the subareas was accomplished by the Muskingum Method that is described in EM 1110-2-1408, "Routing of Floods Through River Channels." An analysis of recorded flood hydrographs to determined routing coefficients cannot be satisfactorily completed because of the large amount of intervening drainage area between the Holbrook and Woodruff gages, as well as the fact that the Hunt gage was discontinued in September 1972. Velocity of flow was determined by normal depth calculations from cross sections obtained from field inspections and 1:62,500 scale topo sheets. An average velocity of 5 feet per second was determined reasonable for the channel reaches. Muskingum "X" values were estimated from field observation, topographic maps, and the amount of overbank indicated by the normal depth calculations. Muskingum coefficients and reach lengths of the various reaches are given in table F-6.

Standard Project Flood Peak Discharge

32. The standard project flood peak discharge at Holbrook, Arizona is approximately 107,000 cfs. Plate F-14 shows the standard project flood hydrograph at Holbrook.

Table F-6. Reach length and muskingum routing coefficients

Channel reach	Reach length (Feet)	Travel time (Hrs)	K (Hrs)	X	No. of subreaches
From areas A & B to C	73,900	4.1	0.50	0.20	8
From area C to D & E	147,800	8.2	0.50	0.20	16
From areas D & E to F & G	82,200	4.5	0.50	0.20	8

DISCHARGE-FREQUENCY ANALYSIS

General

33. Of the eight streamgages that were located in the vicinity of the Little Colorado River, only four are judged to be representative of the flows at Holbrook. They are: (1) the Little Colorado River near Joseph City; (2) the Little Colorado River at Holbrook; (3) the Little Colorado River at Woodruff; and (4) the Little Colorado River near Hunt. The gage at Holbrook was correlated with the Woodruff and Hunt gages, and its period of record extended using the HEC regional frequency program. The record of the gage near Joseph City (5 miles downstream from Holbrook) was used to determine the flows at Holbrook for the missing years of 1974 to 1976.

Analytical Discharge-Frequency Analysis

34. A discharge-frequency relationship for the Little Colorado River at Holbrook was established according to the Water Resources Council's Bulletin 17 "Guidelines for determining floodflow frequency." The statistics of the recorded data for each gage and the adopted statistics for the extended record of the Holbrook gage are shown in table F-7. Plate 1 of Bulletin 17 shows the generalized skew for the Holbrook area to be zero and following the guidelines the computed skew of the extended record is 0.044. In light of the zero skew of Bulletin 17 and the skew of 0.044 of the data, it was judged that a zero skew be adopted for the Holbrook area.

Table F-7. Discharge-frequency statistics.

GAGE (Name and number)	RECORDED Mean	RECORDED Standard deviation	ADOPTED Mean	ADOPTED Standard deviation
Little Colorado River:				
At Holbrook 09397000	3.969	0.268	4.038	0.297
Near Woodruff 09394500	3.606	0.295	--	--
Near Hunt 09388000	2.881	0.491	--	--

35. In addition to the recorded discharges, a peak discharge of 60,000 cfs was plotted as an historical peak. This peak discharge was estimated from slope-area measurements for the flood of September 19, 1923, and judged to be the largest peak to occur since 1870. This event was plotted as the largest event to occur in a 107-year period (1870-1976) and is shown on plate F-15.

Resultant Discharge-Frequency Curve

36. The computed discharge frequency curve for the Little Colorado River at Holbrook (pl. F-15) was drawn with the adopted mean and standard deviation, and with a zero skew. The expected probability curve is represented by the light dashed line. The recorded peak discharges for the Little Colorado River at Holbrook were plotted using median plotting positions.

INTERIOR DRAINAGE

General

37. A possible source of flooding of the City of Holbrook, other than from the Little Colorado River, could occur from the many small streams that flow from the mesa immediately north of the town and from tributaries south of the river flowing into inhabited areas. To determine the severity of the flooding, the standard project, 100-year, and 50-year floods were computed for concentration points within the City of Holbrook.

38. In order to adequately define the the interior drainages of Holbrook, it was necessary to divide the city into subareas and route and combine flows where necessary. Subarea locations and drainage boundaries are shown on plate F-16. The subareas range in size from 1.60 to 0.06 square miles and have slopes ranging from 9 feet per mile to almost 200 feet per mile.

Standard Project Flood

39. The standard project flood for the interior drainages of Holbrook was judged to occur from a high intensity, short-duration summer thunderstorm centered over the city. The summer thunderstorm that occurred at Queen Creek, Arizona, in August 1954 is a good example of this type of flood-producing event. A summer thunderstorm of this intensity could occur in the Holbrook area and would be reasonable for use as the standard project storm. The Queen Creek storm pattern was transposed to the Holbrook area by ratios of 10-year, 6-hour precipitation; and as a result, the total rainfall at the storm center was reduced from 7.50 inches to 4.74 inches.

40. Runoff was computed using synthetic unit hydrographs developed for the subarea using the Average Arizona (under 1,500 sq. miles) S-graph. Basin "N" values ranged from 0.30 to 0.045. Pertinent data for the various subareas are given in table F-8. Because of the lack of rainfall-runoff data, precipitation-loss rates could not be determined by reconstitutions. A loss rate of 0.25 inch per hour was judged to be a representative loss rate for the Holbrook area following experience with other hydrologically similar areas. Imperviousness ranged from 5 to 25 percent.

Table F-8. Interior drainage subarea characteristics.

Subarea designation	Drainage Area (Sq. miles)	L (Miles)	Lca (Miles)	Slope (Ft/mile)	"N" Value	Percent impervious
A	1.60	2.46	1.42	65	0.045	5
B	0.49	0.85	0.42	200	0.040	10
C	0.31	0.96	0.46	180	0.035	10
D	0.40	1.08	0.45	160	0.040	5
E	1.47	1.96	1.04	130	0.045	5
F	0.26	1.30	0.64	10	0.030	25
G	0.06	0.77	0.35	15	0.030	25
H	0.45	0.91	0.30	130	0.030	5
I	0.29	1.07	0.54	120	0.030	5

41. Flood hydrograph routing between the subareas was accomplished by the Muskingum method. Routing velocities were determined by normal depth calculations from cross-sections obtained from 1:2400 scale topographic maps. Muskingum "X" values ranged from 0.20 in the leveed section at the east side of town to 0.10 in the areas subject to street flow in town. Routing parameters for the various reaches are listed in table F-9.

100- and 50-Year Floods

42. In the absence of any runoff data from small drainage basins in or near the Holbrook area, it was judged that the best estimate of the 100- and 50-year floods would be from rainfall of the same

frequency. The premise adopted in this analysis was that if "average" values of other parameters such as basin "N" values, percent impervious, and loss rates are used, the frequency of the derived flood should approximate the frequency of rainfall.

43. The rainfall parameters chosen to preserve the consistency between rainfall and runoff frequency were the maximum 5-, 10-, 15- and 30-minute nad 1-hour precipitation amounts. The maximum amounts were determined from N-year, 6-hour, and N-year, 24-hour rainfall amounts and regression equations for finding N-year, T-hour amounts presented in NOAA Atlas 2. The time-distribution pattern chosen was the same as the one used for the SPF, the Queen Creek storm.

Table F-9. Muskingum routing coefficients.

Reaches	Travel time (hrs)	No. of Subreaches	Muskingum K (Subreaches)	Muskingum K
Subareas				
A to B*	0.23	3	0.083	0.10
B to C	0.26	3	0.083	0.15
C to D	0.26	3	0.083	0.10
A to E	0.09	1	0.09	0.20
E to F*	0.60	8	0.083	0.10
F to G	0.24	3	0.083	0.10

* Breakout from levee.

44. The 100- and 50-year flood peak discharges were calculated in the same manner as the SPF. Basin "N" values, loss rates and routing coefficients were adjusted to account for the inefficiency of the drainage basin under less than standard project conditions.

45. Because of the lack of any streamgages in the Holbrook area, it was necessary to examine all possible gages within a 75-mile radius of Holbrook to see if any discharge-frequency relationships could be established for use in the study. Table F-10 presents a listing of 18 crest-stage gages used for analysis. It was judged that the adequacy of the 100- and 50-year flood peak discharges could be indicated by comparison with the 100- and 50-year discharges computed from the gages using the guidelines of Bulletin 17. A comparison of the computed 100- and 50-year peak discharges for the concentration points with those of the stream gages are shown on plates F-17 and F-18.

Peak Discharges

46. Standard project and N-year flood peak discharges for project and nonproject conditions within the City of Holbrook are listed in table F-11 and shown on plates F-19 and F-20.

Coincident Flows

47. Coincident flows for the Little Colorado River and the tributaries within the City of Holbrook were determined from an analysis of maximum 1-day rainfalls recorded at Holbrook and maximum 1-day flows in the Little Colorado River. From the analysis it was determined that when the 100-year flood peak occurred on the tributaries, the flow on the Little Colorado River would be equal to a 5-year flood. From the same analysis, a 10-year flood could be expected on the tributaries when the 100-year flood is occurring on the Little Colorado River.

Table F-10. Crest-stage stream gages in the vicinity of Holbrook.

Gage Number (U.S.G.S. No.)	Location	Drainage area (Sq. miles)	Years of record	Mean	Standard deviation	100-Year peak	50-Year peak
09383600	Fish Creek near Eagar, Ariz.	17.2	13	1.6534	0.7453	696 cfs	583 cfs
09384200	Lyman Reservoir Trib near St. Johns, Ariz	0.24	13	1.3228	0.6439	211 cfs	183 cfs
09385800	Little Colorado River Trib. near St. Johns, Ariz.	0.35	13	1.7728	0.4506	953 cfs	634 cfs
09395100	Carr Lake Draw Trib. near Holbrook, Ariz.	1.19	12	1.5634	0.5636	283 cfs	244 cfs
09395200	Decker Wash near Snowflake, Ariz.	16.8	14	1.4160	1.2091	6,080 cfs	3,370 cfs
09395850	Black Creek Trib. near Window Rock, Ariz.	0.28	13	2.0827	0.1271	237 cfs	219 cfs
09396400	Dead Wash Trib. near Holbrook, Ariz.	1.00	13	2.2728	0.3762	1,410 cfs	1,110 cfs
09397200	Penzance Wash near Joseph City, Ariz.	0.17	13	1.3922	0.6760	304 cfs	257 cfs
09397800	Brookbank Canyon near Heber, Ariz.	27.6	12	1.8099	0.9238	9,100 cfs	5,090 cfs
09399420	Jacks Canyon Trib. No.3 near Winslow, Ariz.	0.25	13	1.9190	0.4825	316 cfs	302 cfs

Table F-10. Continued

Gage Number (U.S.G.S No.)	Location	Drainage area (Sq. miles)	Years of record	Mean	Standard deviation	100-Year peak	50-Year peak
09400100	Ganado Wash Trib. near Ganado, Ariz.	11.1	13	2.0201	1.0039	22,700 cfs	12,100 cfs
09400200	Steamboat Wash Trib. near Ganado, Ariz.	0.32	13	1.4767	0.8995	3,710 cfs	2,110 cfs
09400290	Teshbito Wash Trib. near Holbrook, Ariz.	16.4	12	2.5339	0.5009	5,000 cfs	3,650 cfs
09400300	Teshbito Wash near Holbrook, Ariz.	57.4	13	2.7726	0.3618	4,110 cfs	3,280 cfs
09400530	Cow Canyon near Winslow, Ariz.	7.49	13	1.4077	1.0591	555 cfs	496 cfs
09400560	Oraibi Wash Trib. near Oraibi, Ariz.	1.76	13	2.0283	0.5039	1,590 cfs	1,160 cfs
09400565	Polacca Wash Trib. near Chinle, Ariz.	6.45	12	2.3554	0.7134	10,400 cfs	6,620 cfs
09400580	Castle Butte Wash near Winslow, Ariz.	5.53	12	1.7740	1.0535	3,800 cfs	2,700 cfs

Table F-11. Standard project and 100-year flood peak discharges for interior drainages of Holbrook.

Concentration	Drainage area (Sq. miles)	Standard project flood (cfs) (W/proj)	Standard project flood (cfs) (W/o proj)	100-Year flood peak (cfs) (W/proj)	100-Year flood peak (cfs) (W/o proj)
Airport trib.					
At beginning of levee	1.60	3,050	3,050	1,370	1,370
Downstream from east trib.	3.07	5,720	--	2,510	--
East trib.					
Upstream from airport trib.	1.47	3,330	3,330	1,610	1,610
Breakout from airport trib.					
Flow upstream from Stream A	--	--	1,210	--	410
Breakout from levee at Railroad	--	--	2,560	--	220
Stream A					
Flow at Erie St. and 3rd Ave.	0.49	1,500	1,500	900	900
Stream B					
Flow upstream from Buffalo St.	0.31	970	970	570	570
Flow downstream from confl. with stream A	0.80	1,960	2,100	1,010	1,000
Stream C					
Flow upstream from confl. with Stream B	0.40	1,210	1,210	720	720
Flow downstream from confl. with Stream B	1.20	2,400	2,460	1,160	1,130

Table F-11. Continued.

Concentration	Drainage area (Sq. miles)	Standard project flood (cfs) W/proj)	Standard project flood (cfs) (W/o proj)	100-Year flood peak (cfs) (W/proj)	100-Year flood peak (cfs) (W/o proj)
Stream D					
Flow at 12th St. and Central Ave.	0.26	660	2,380	340	380
Flow at railroad embankment	0.32	680	2,320	340	340
Combined Flows					
Downstream from railroad embankment	1.52	3,030	3,130	1,450	1,450
Stream E					
Flow at U.S. 260 and State 77	0.45	1,660	1,660	960	960
Stream F					
Flow at Apache R.R.	0.29	1,000	1,000	530	530

ADEQUACY OF RESULTS

Standard Project Flood

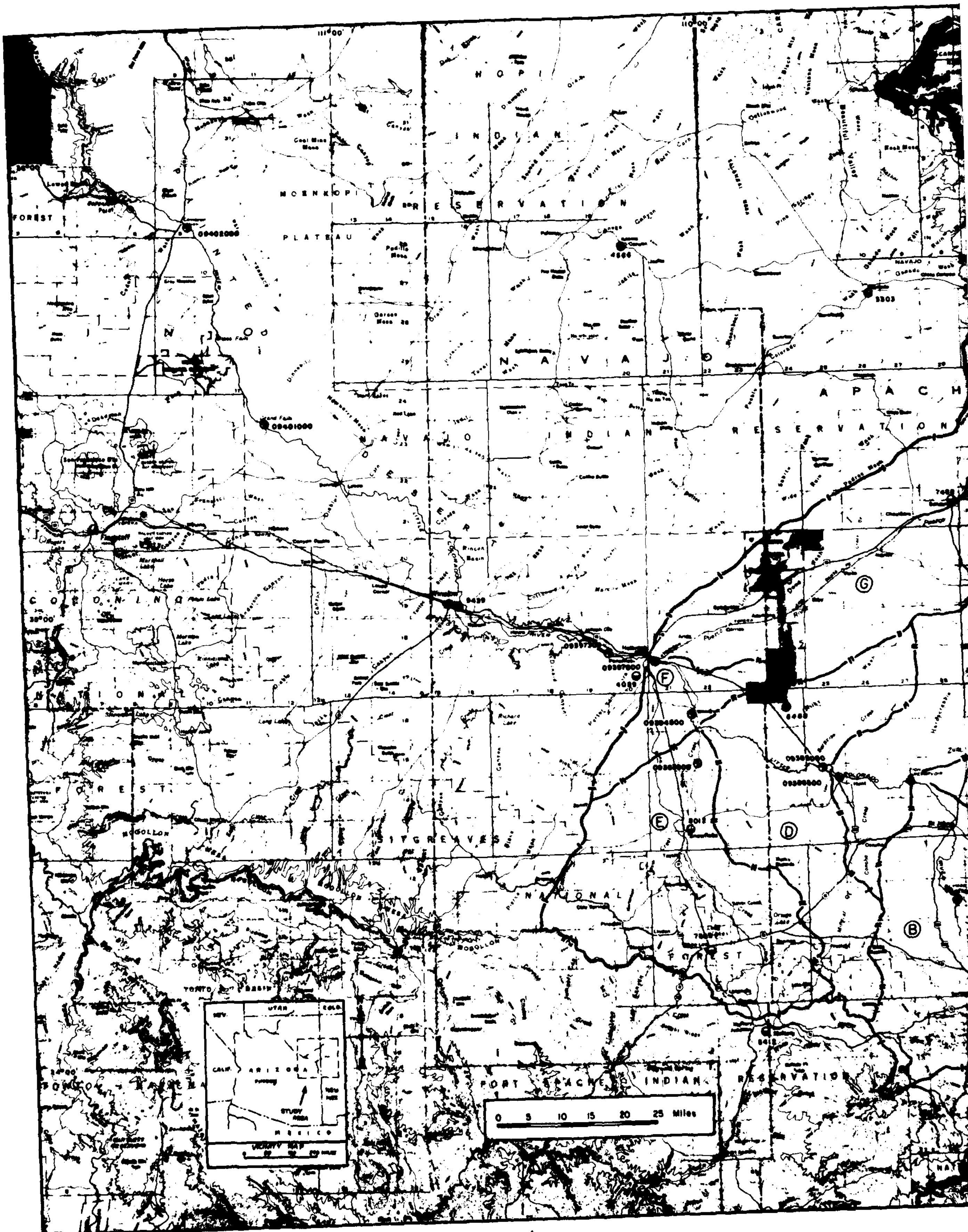
48. The adequacy of the standard project flood discharge is indicated by comparison with the enveloping curves or recorded discharges shown on plate F-21.

Probable Maximum Flood (PMF)

49. An evaluation of the probable maximum flood was completed for comparison with the SPF from the 1970 storm transposition. General storm probable maximum precipitation (PMP) criteria of the southwest areas has not been finalized; therefore, its use is limited to only rough estimates. In addition, the areal reduction for covergence and orographic PMP is limited to less than 5,000 square miles in the preliminary criteria; the Little Colorado River at Holbrook has a drainage area of 11,400 square miles.

50. Two computations of PMF were made using the new criteria. With the areal reduction factor limited to areas of under 5,000 square miles, the PMP was centered over only 5,000 square miles of the drainage basin above Holbrook. Choice of probable maximum storm centering was based on a comparison of the basin average orographic index for all subareas. The lowest indices were of the Zuni and Puerco River subareas, totaling almost 6,000 square miles. These two subareas were considered as noncontributing for this computation. The PMF peak at Holbrook by this method is 227,000 cfs.

51. The second computation of the PMF was made by extrapolating the areal reduction curves from the 5,000 square miles to the 11,400 square miles needed for Holbrook. Unlike the first computation, all the subareas were considered to be contributing to the peak at Holbrook. This method yields a PMF of 206,000 cfs. Hydrographs of both floods and the SPF are shown on plate F-22.



HOPI
INDIAN
RESERVATION
MOENKOPI
PLATEAU
NAVAJO
APACHE
RESERVATION
NAVAJO INDIAN
COCONINO
NATIONAL
FOREST
MOGOLLON
SITGREAVES
NATIONAL
FOREST
FORT APACHE INDIAN RESERVATION
0 5 10 15 20 25 Miles
UTAH
COLO.
NEV.
CALIF.
ARIZONA
MEXICO
VICINITY MAP

1

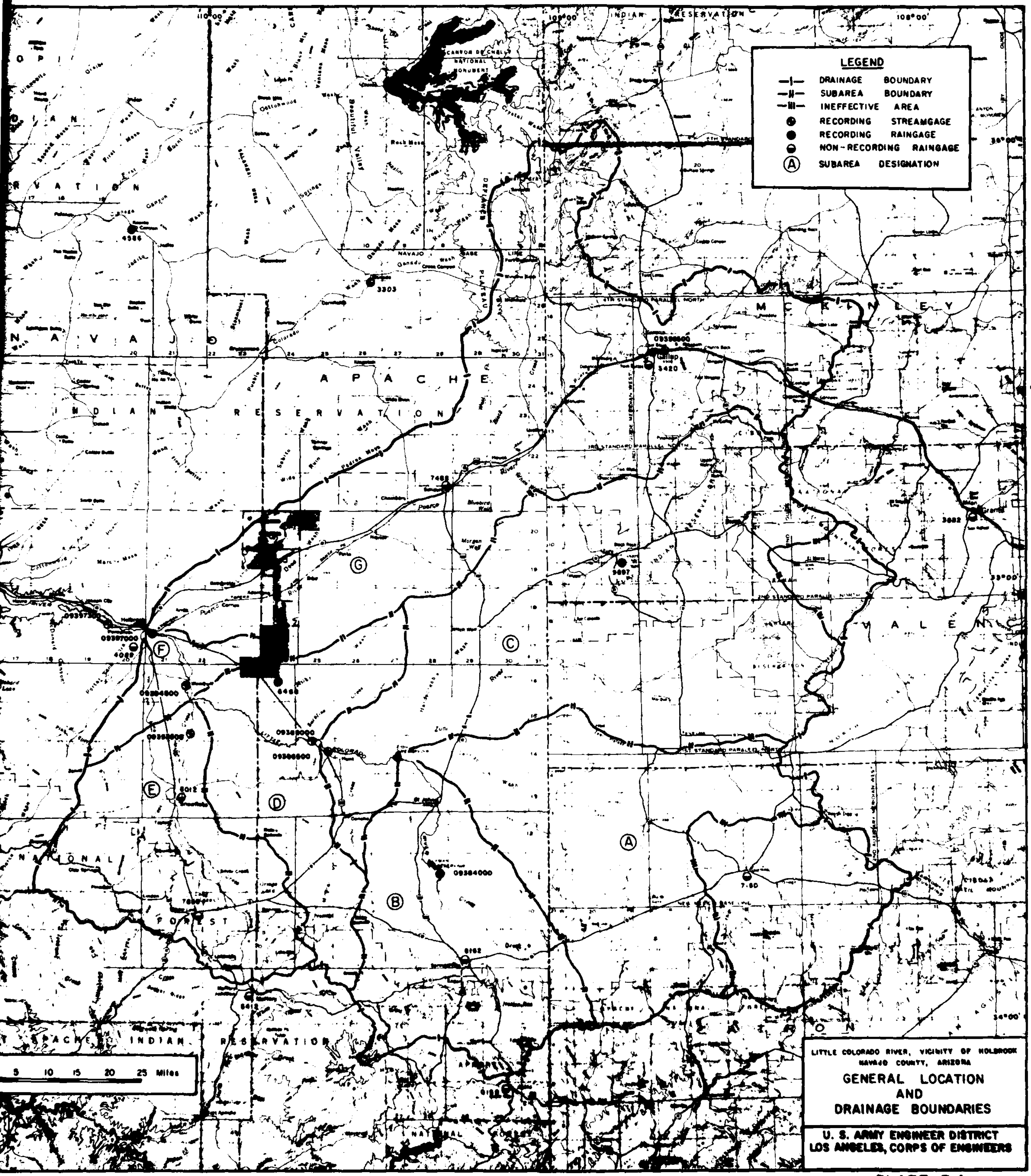
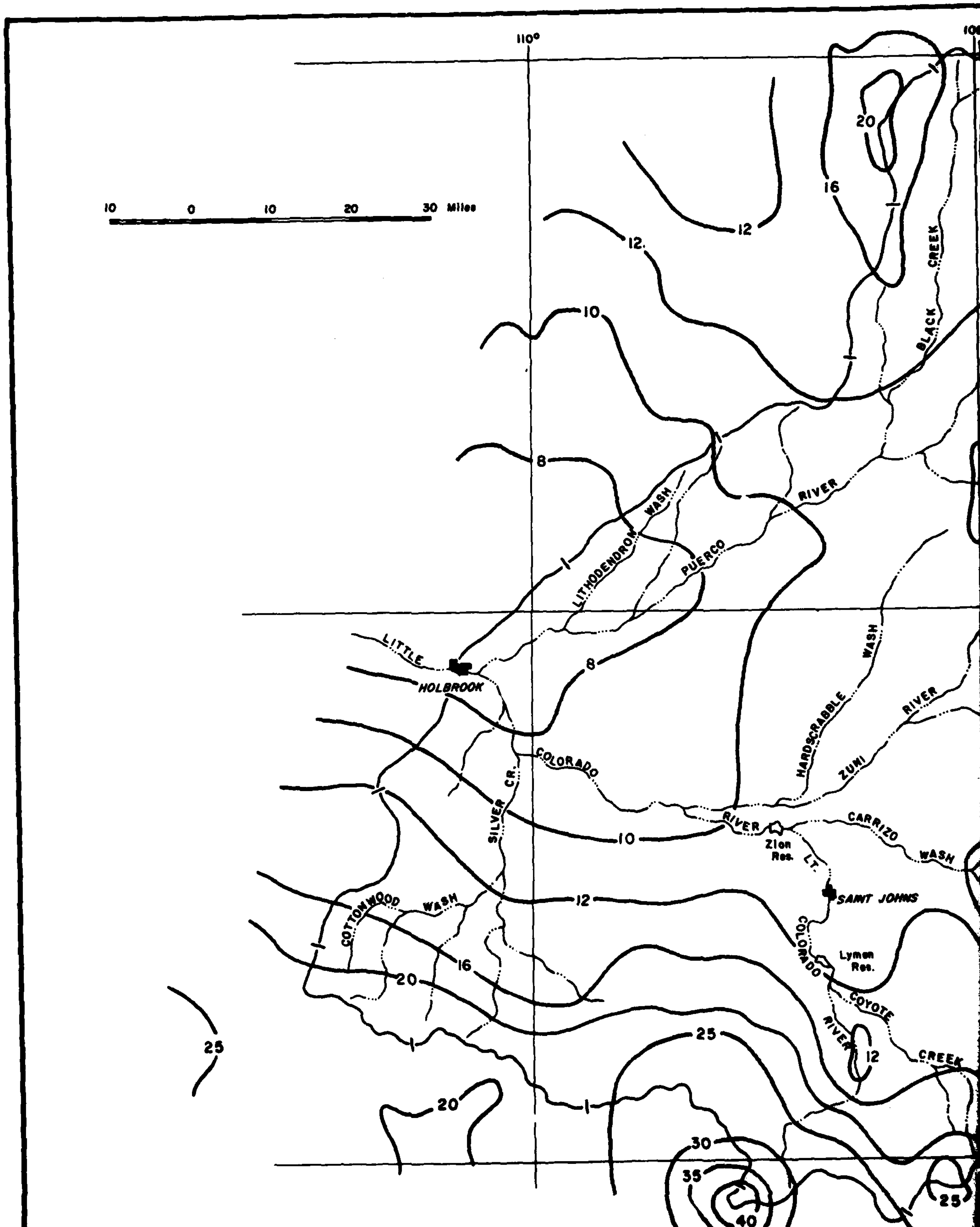

LEGEND
DRAINAGE BOUNDARY
SUBAREA BOUNDARY
INEFFECTIVE AREA
RECORDING STREAMGAGE
RECORDING RAINGAGE
NON-RECORDING RAINGAGE
SUBAREA DESIGNATION
A
B
C
D
E
F
G
APACHE
INDIAN RESERVATION
NAVAJO
MCKINLEY
VALENCIA
NATIONAL FOREST
5 10 15 20 25 Miles
LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA
GENERAL LOCATION
AND
DRAINAGE BOUNDARIES
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE F-1



110°
10 0 10 20 30 Miles
BLACK CREEK
LITHODENDRON WASH
PUERCO RIVER
LITTLE COLORADO
HOLBROOK
SILVER CR.
COTTONWOOD WASH
HARDSCRABBLE WASH
ZUNI RIVER
CARRIZO WASH
Zion Res.
SAINT JOHNS
Lyman Res.
COYOTE CREEK
RIVER
8
10
12
16
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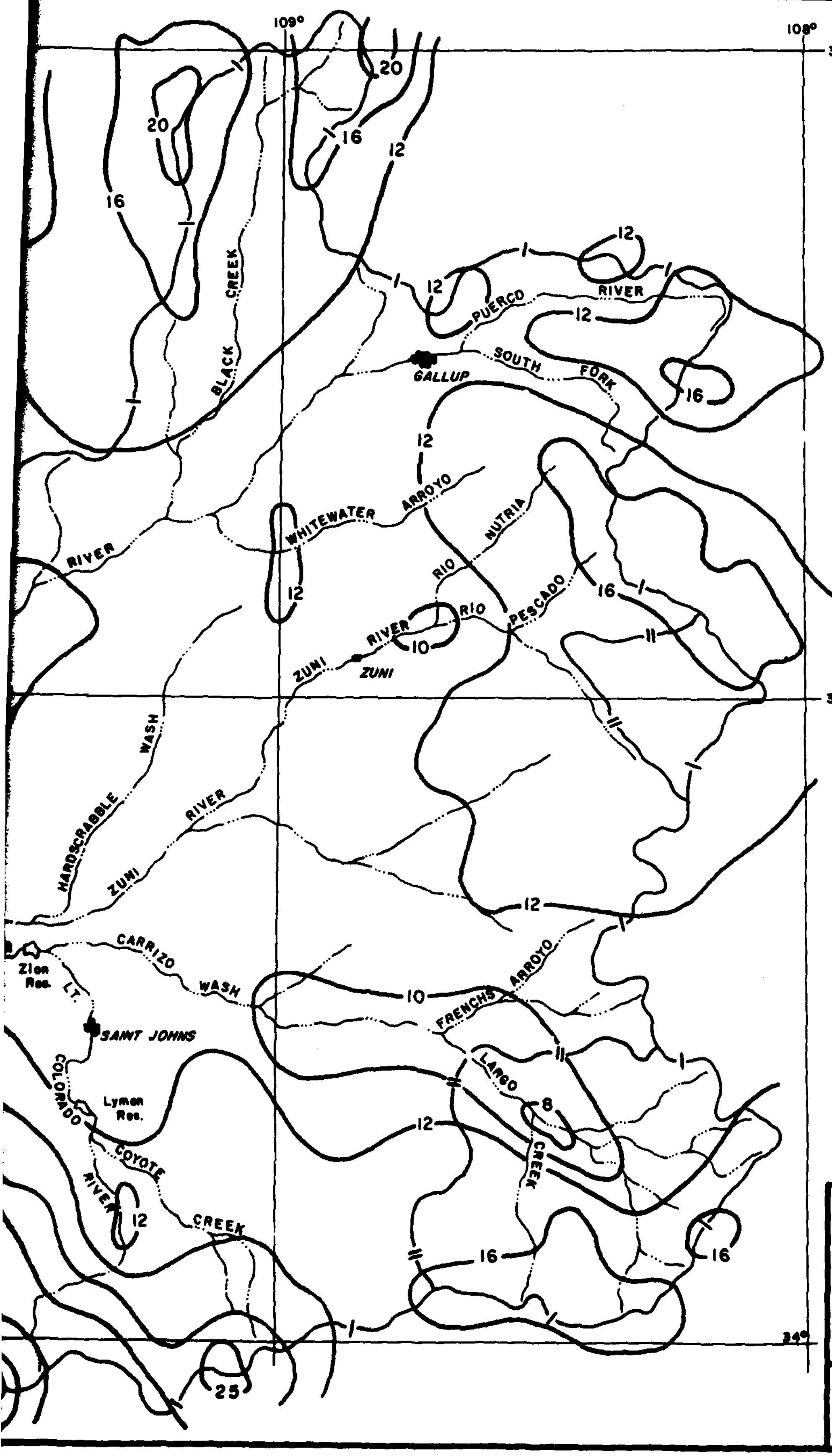
25
30
35
40



NORMAL ANNUAL PRECIPITATION
IN INCHES
1931 - 1960

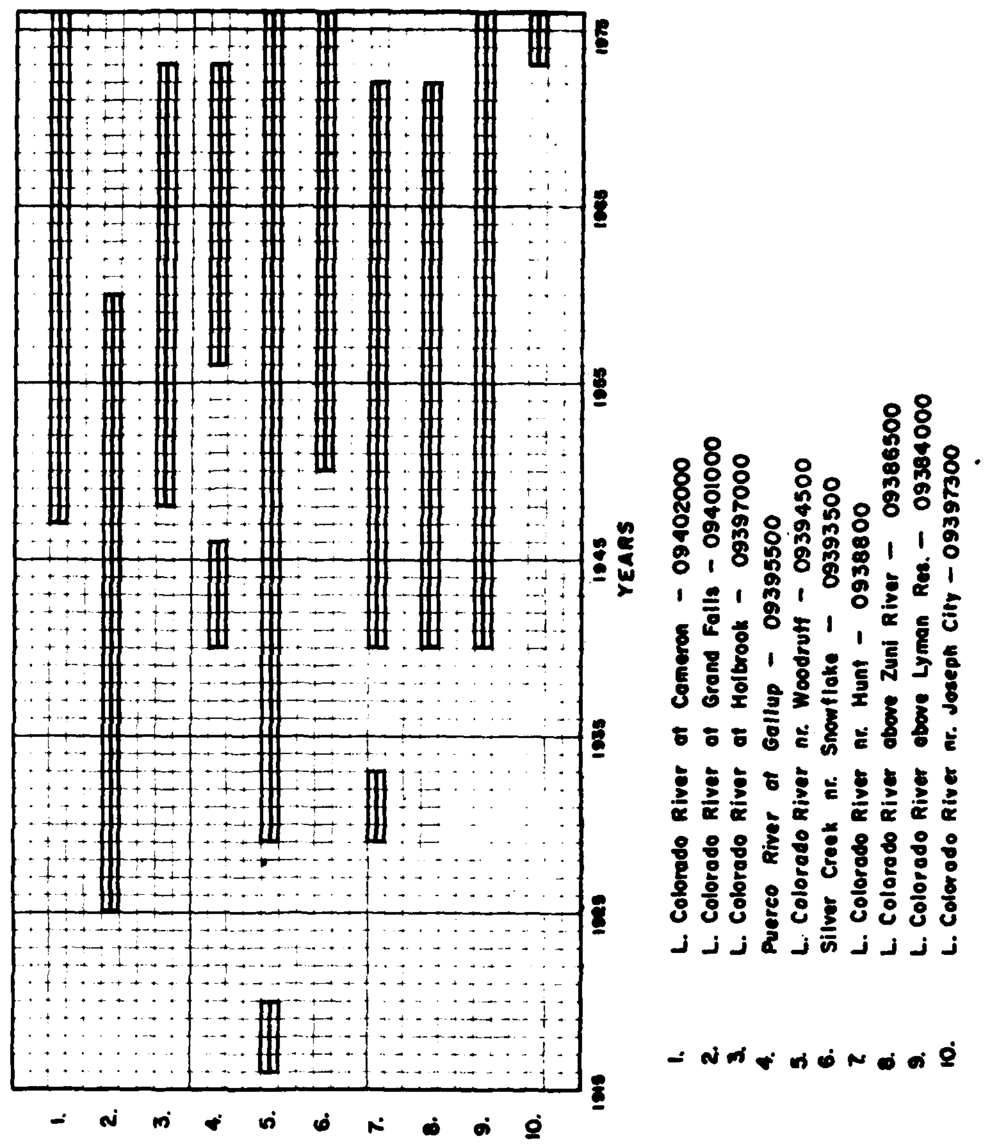
LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

NORMAL ANNUAL
PRECIPITATION

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

9

PLATE F-2



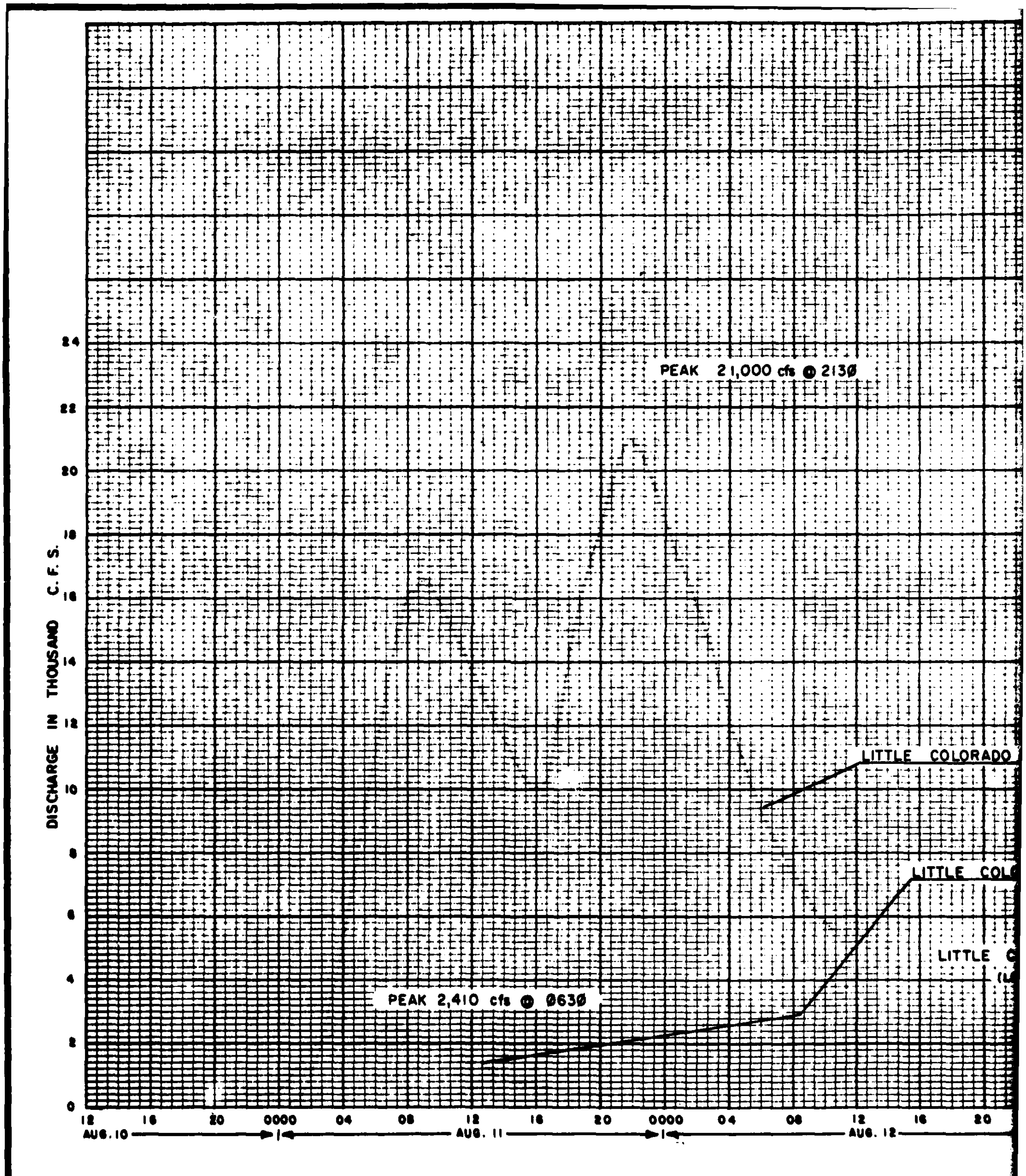
LENGTH OF RECORD OF GAGING STATIONS

LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

U.S. GEOLOGICAL SURVEY
STREAM GAGING STATIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE F-3



DISCHARGE IN THOUSAND C. F. S.
PEAK 21,000 cfs @ 213Ø
LITTLE COLORADO
LITTLE COLO
LITTLE C
PEAK 2,410 cfs @ Ø63Ø
0
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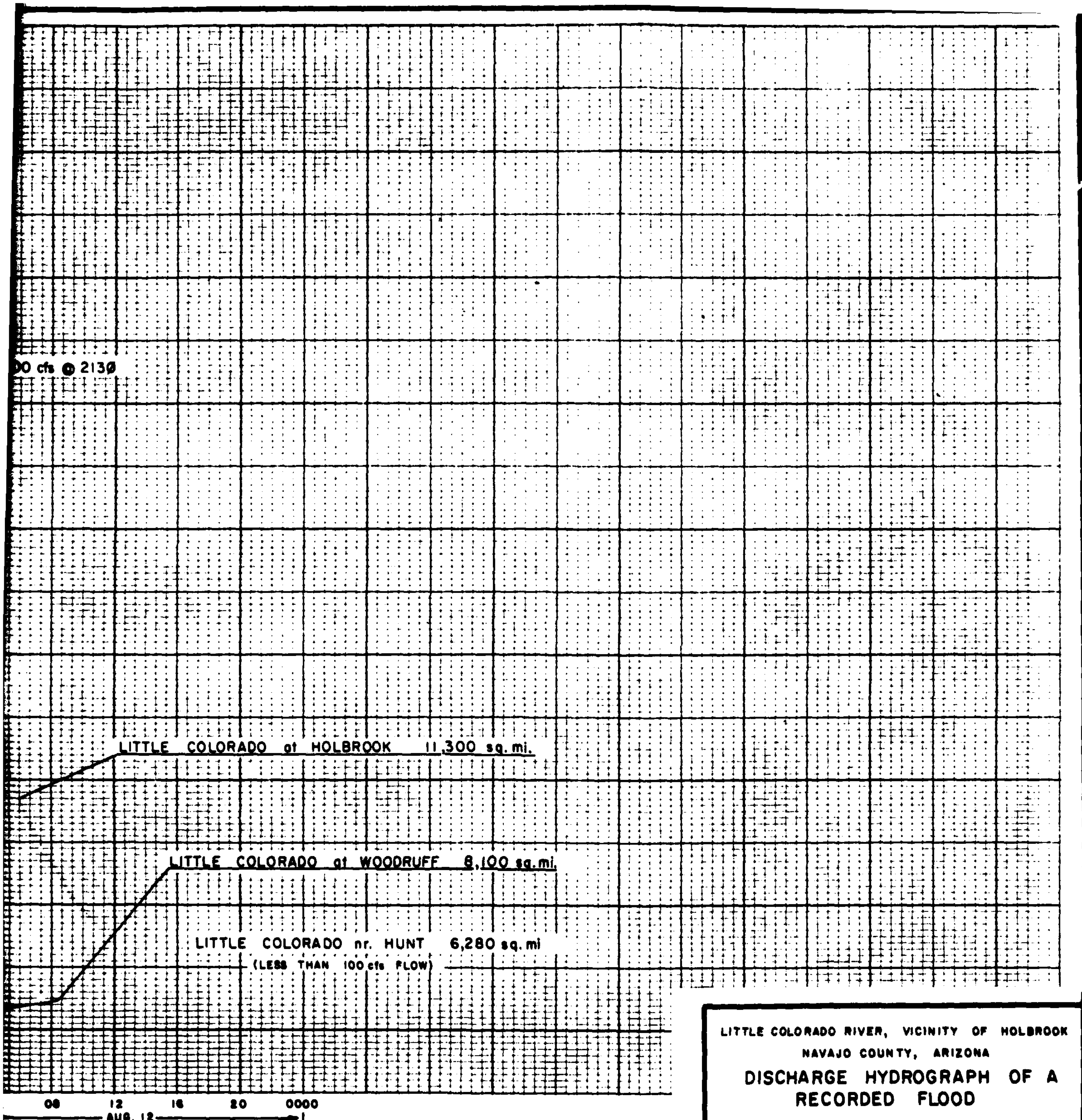
AUG. 12

1

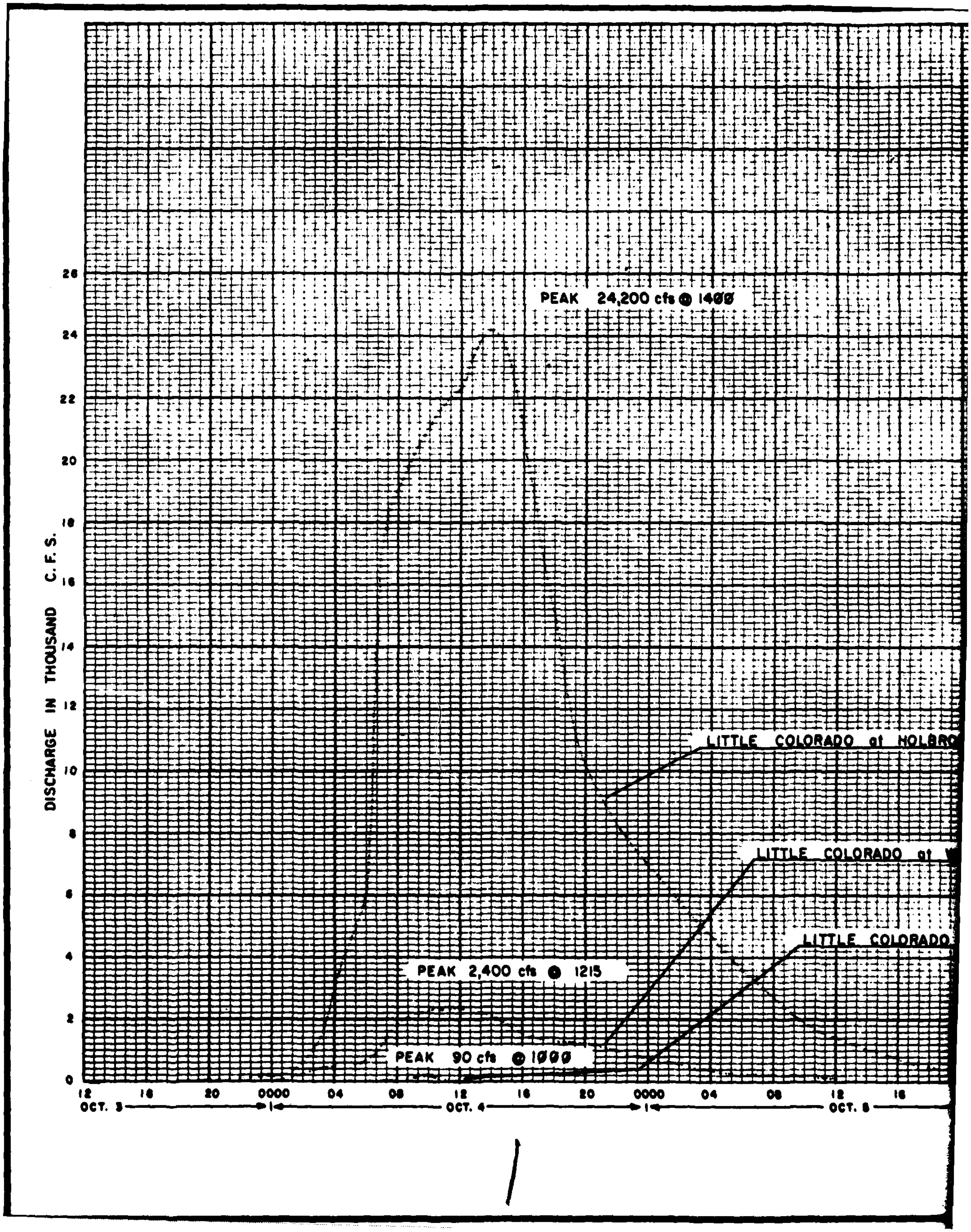


LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

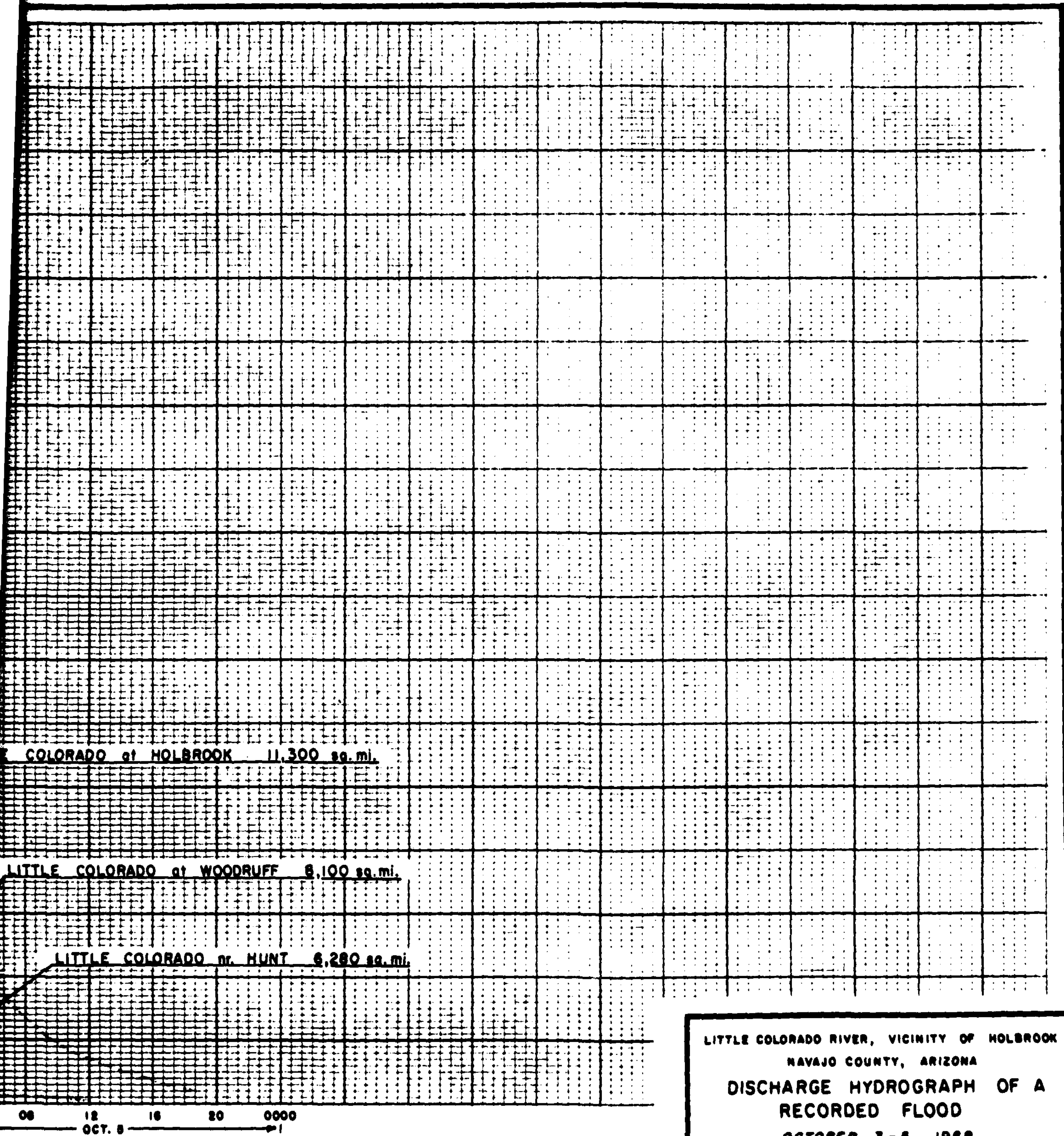
DISCHARGE HYDROGRAPH OF A RECORDED FLOOD

AUGUST 10-12, 1968

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS



DISCHARGE IN THOUSAND C.F.S.
PEAK 24,200 cfs @ 1400
LITTLE COLORADO at HOLBRO
LITTLE COLORADO at W
LITTLE COLORADO
PEAK 2,400 cfs @ 1215
PEAK 90 cfs @ 1000
OCT. 3
OCT. 4
OCT. 5

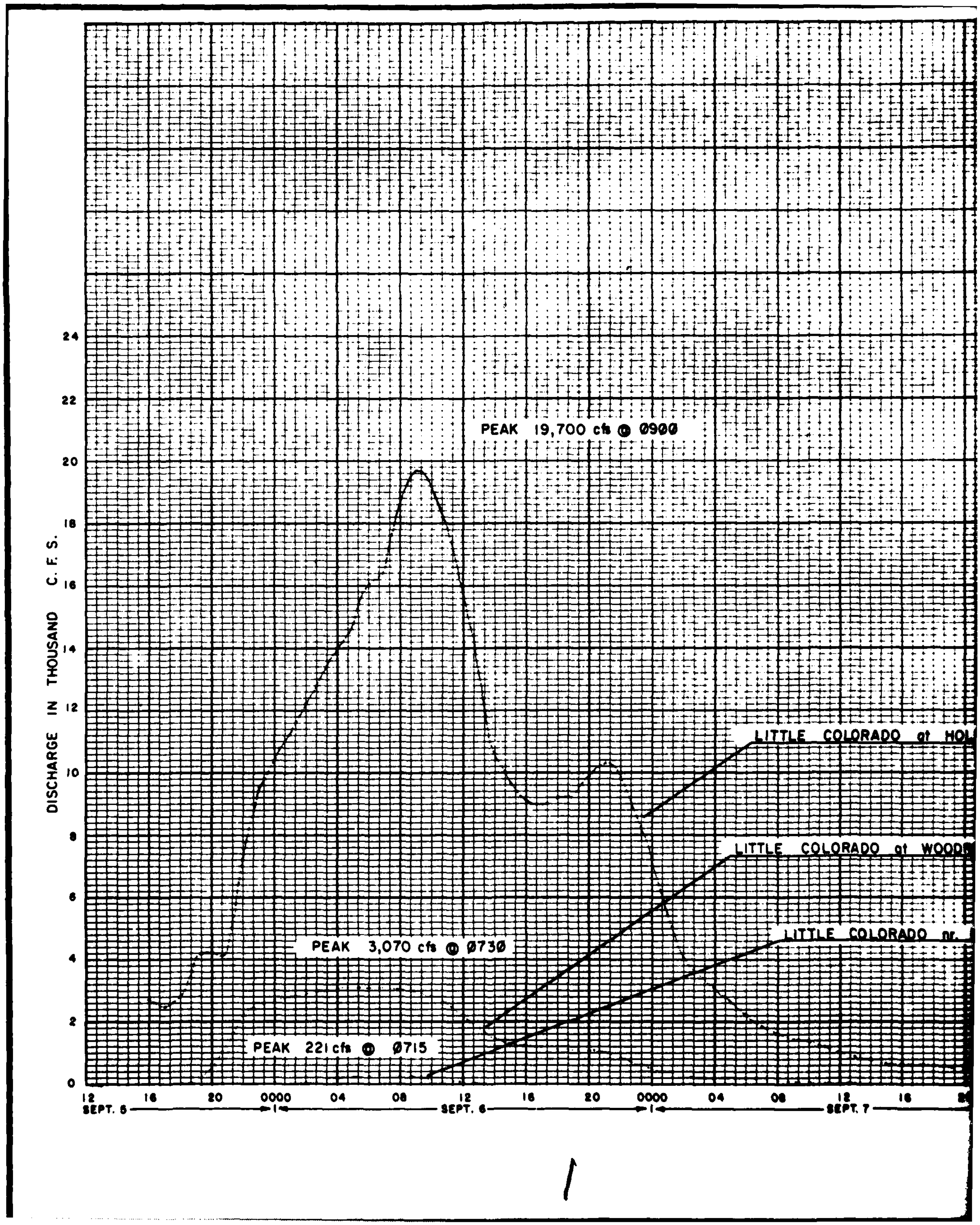


LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

DISCHARGE HYDROGRAPH OF A RECORDED FLOOD

OCTOBER 3-5, 1968

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS



DISCHARGE IN THOUSAND C. F. S.
24
22
20
18
16
14
12
10
8
6
4
2
0
PEAK 19,700 cfs @ 0900
PEAK 3,070 cfs @ 0730
PEAK 221 cfs @ 0715
LITTLE COLORADO at HOL
LITTLE COLORADO at WOOD
LITTLE COLORADO nr.
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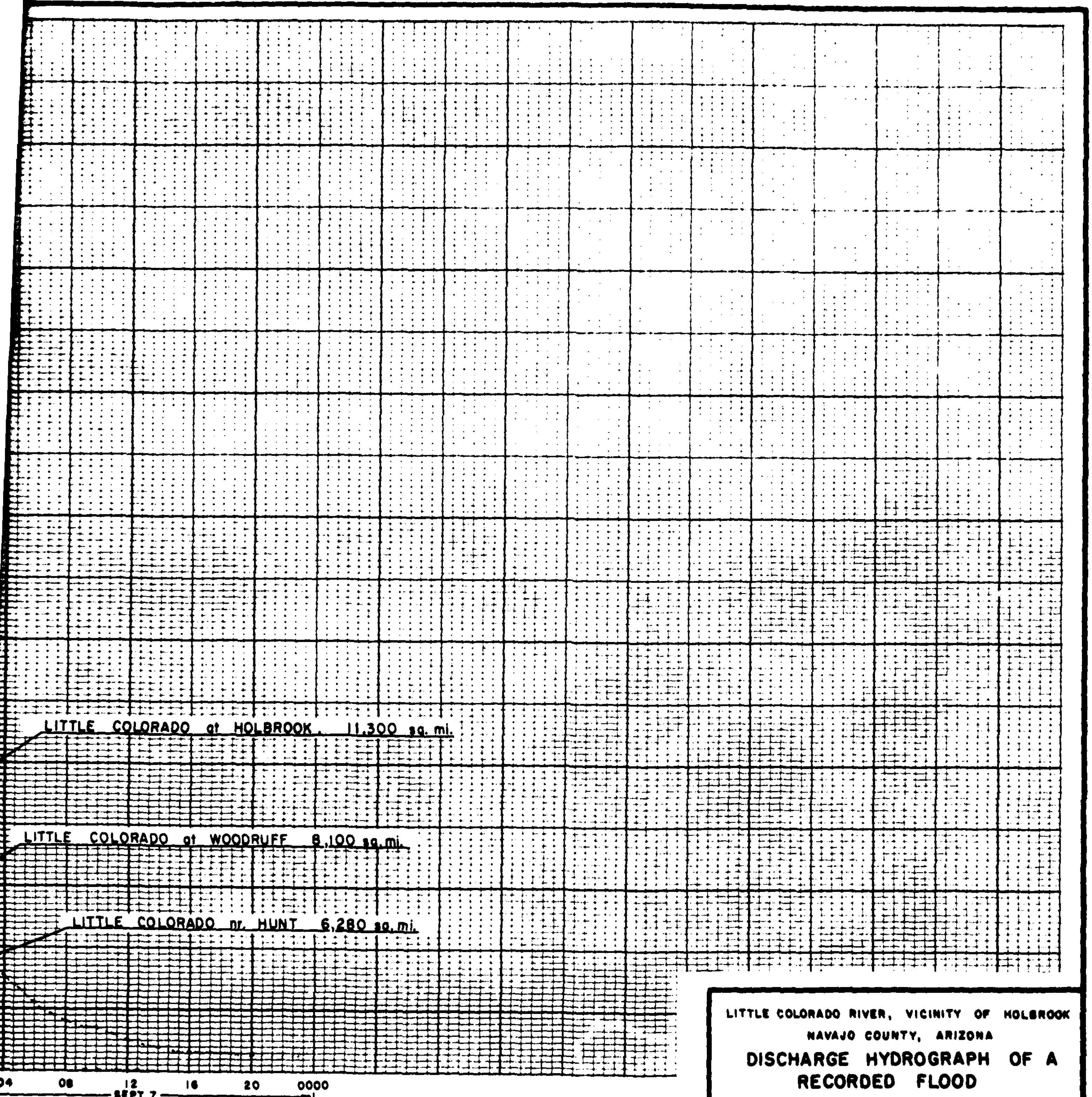
SEPT. 5
SEPT. 6
SEPT. 7

1



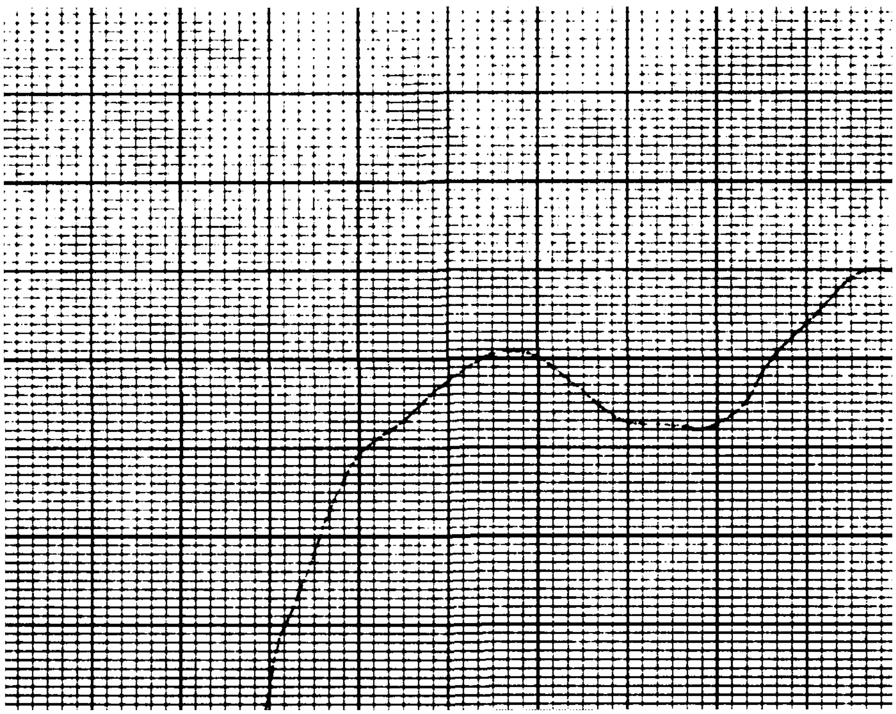
LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

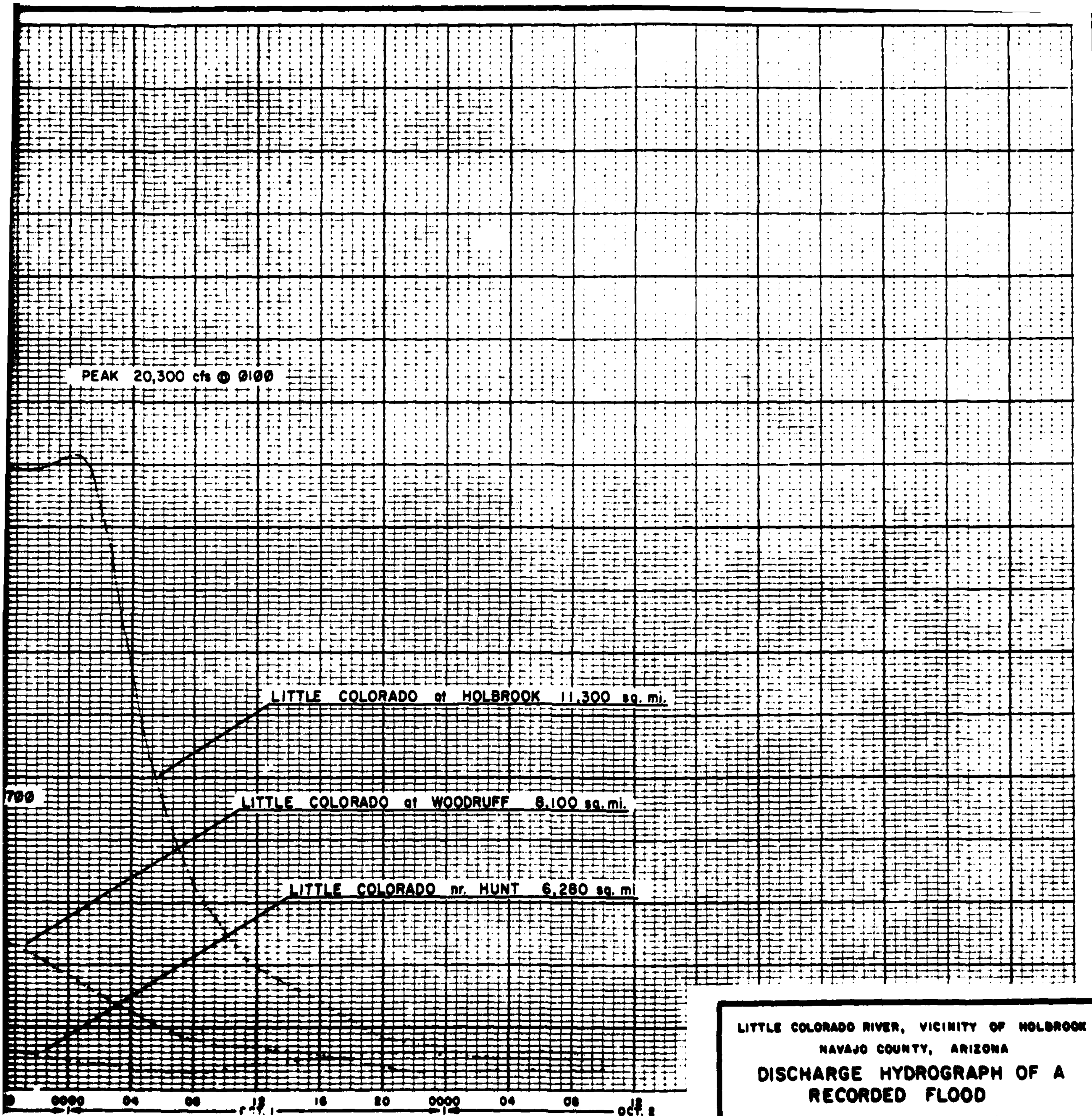
DISCHARGE HYDROGRAPH OF A RECORDED FLOOD

SEPTEMBER 5-7, 1970

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

2 — PLATE F-6



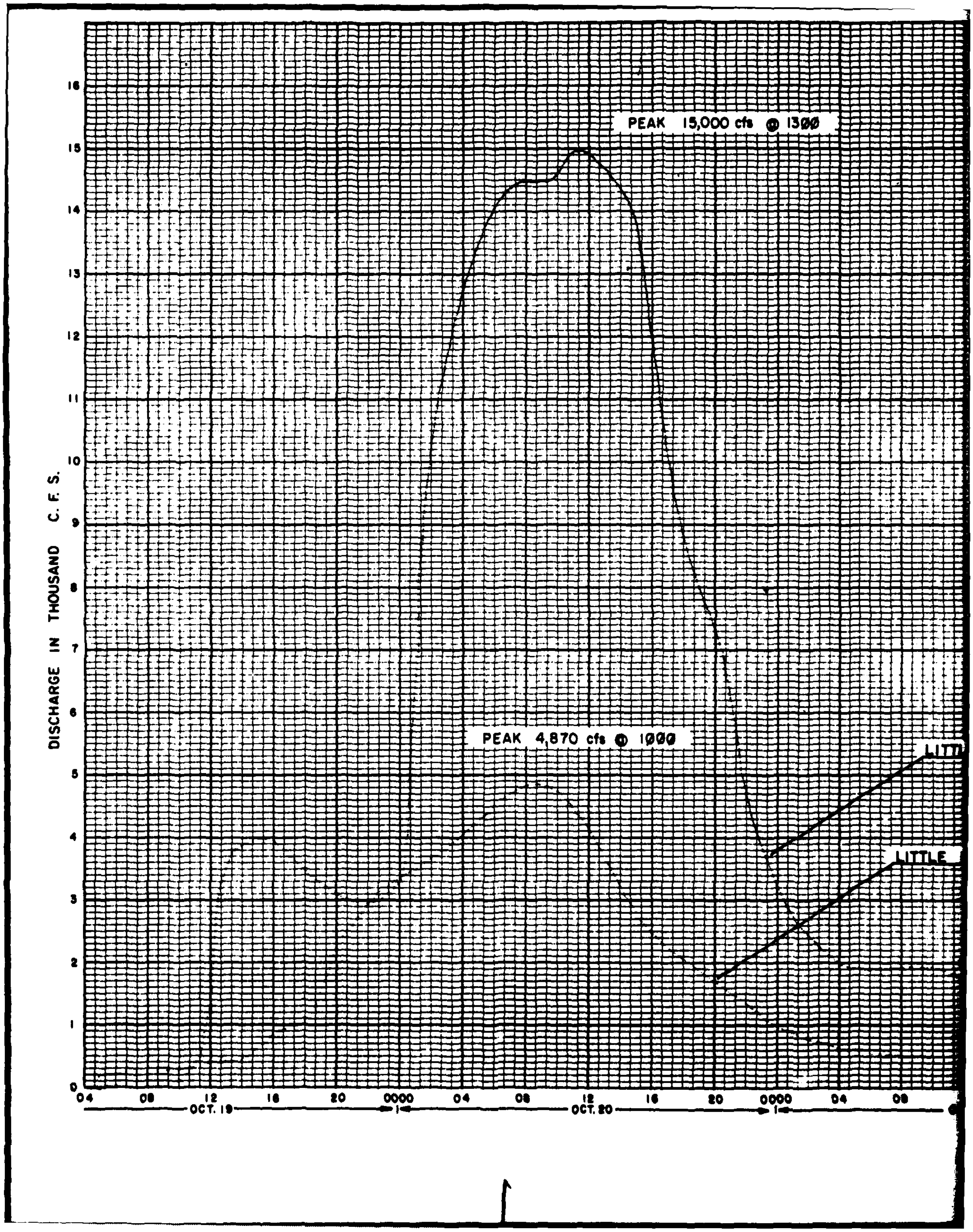


LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

DISCHARGE HYDROGRAPH OF A RECORDED FLOOD

SEPTEMBER 29 - OCTOBER 2, 1971

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS


PEAK 15,000 cfs @ 1300
PEAK 4,870 cfs @ 1000
LITTL
LITTLE
DISCHARGE IN THOUSAND C. F. S.
0
1
2
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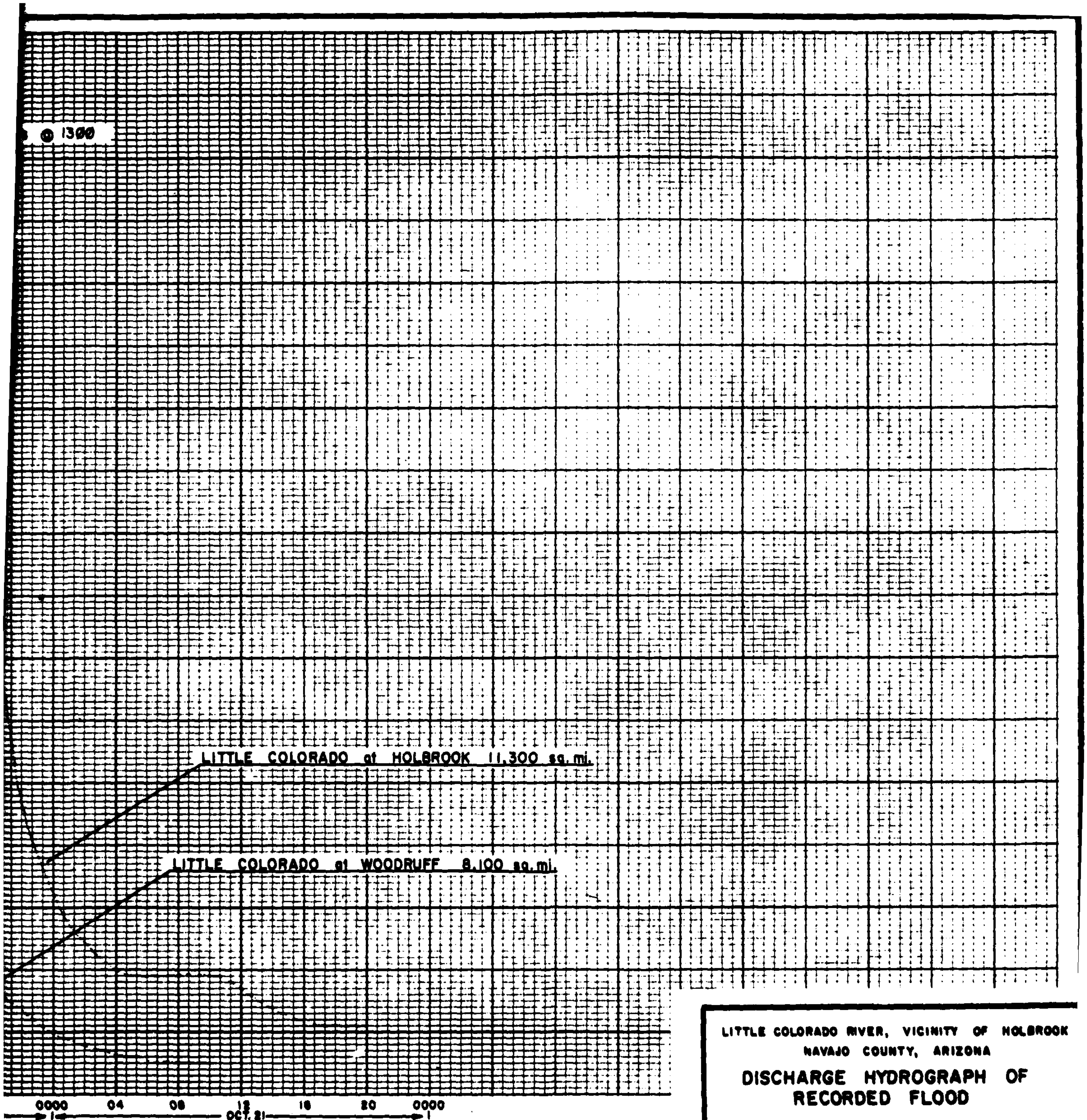
OCT. 19
OCT. 20

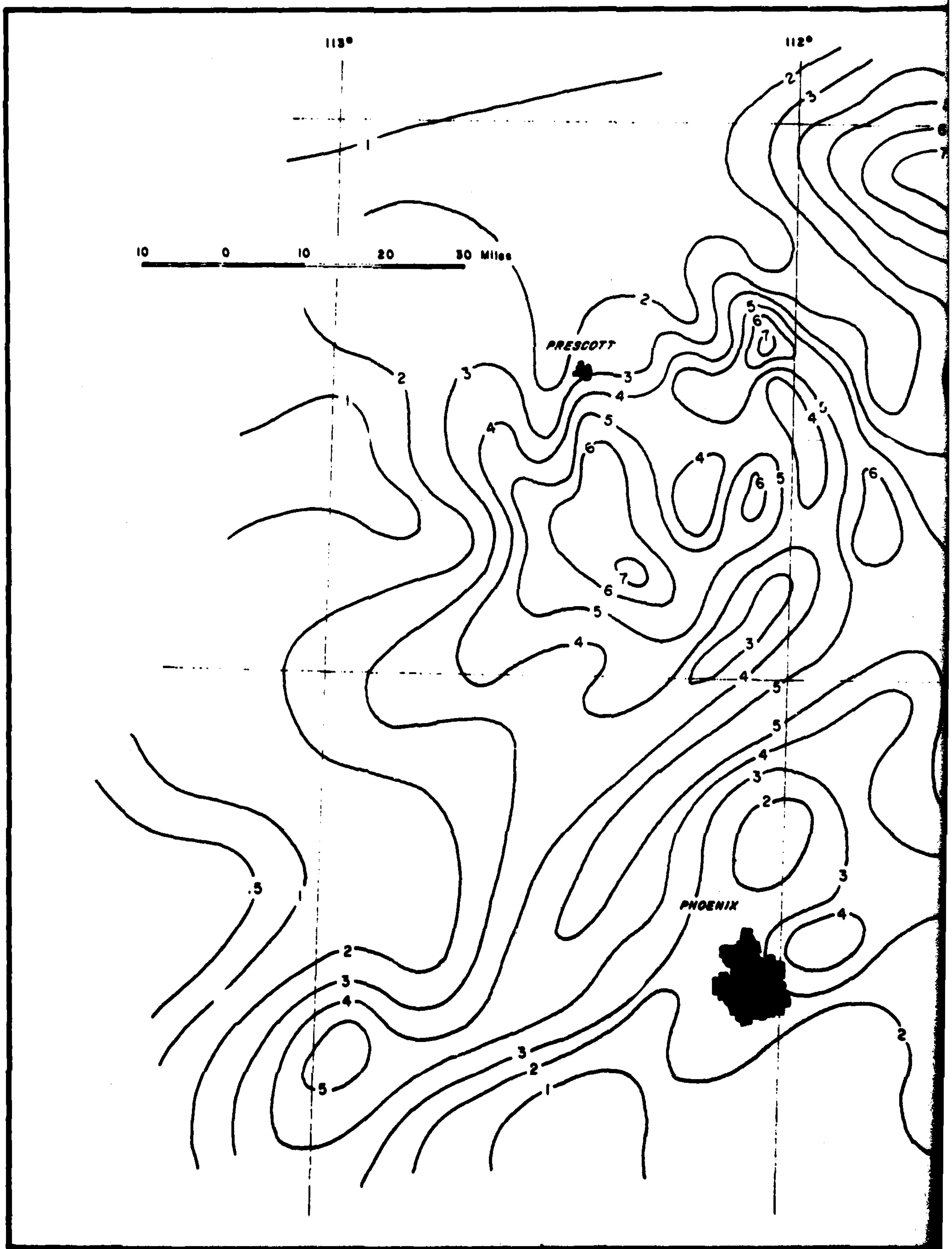


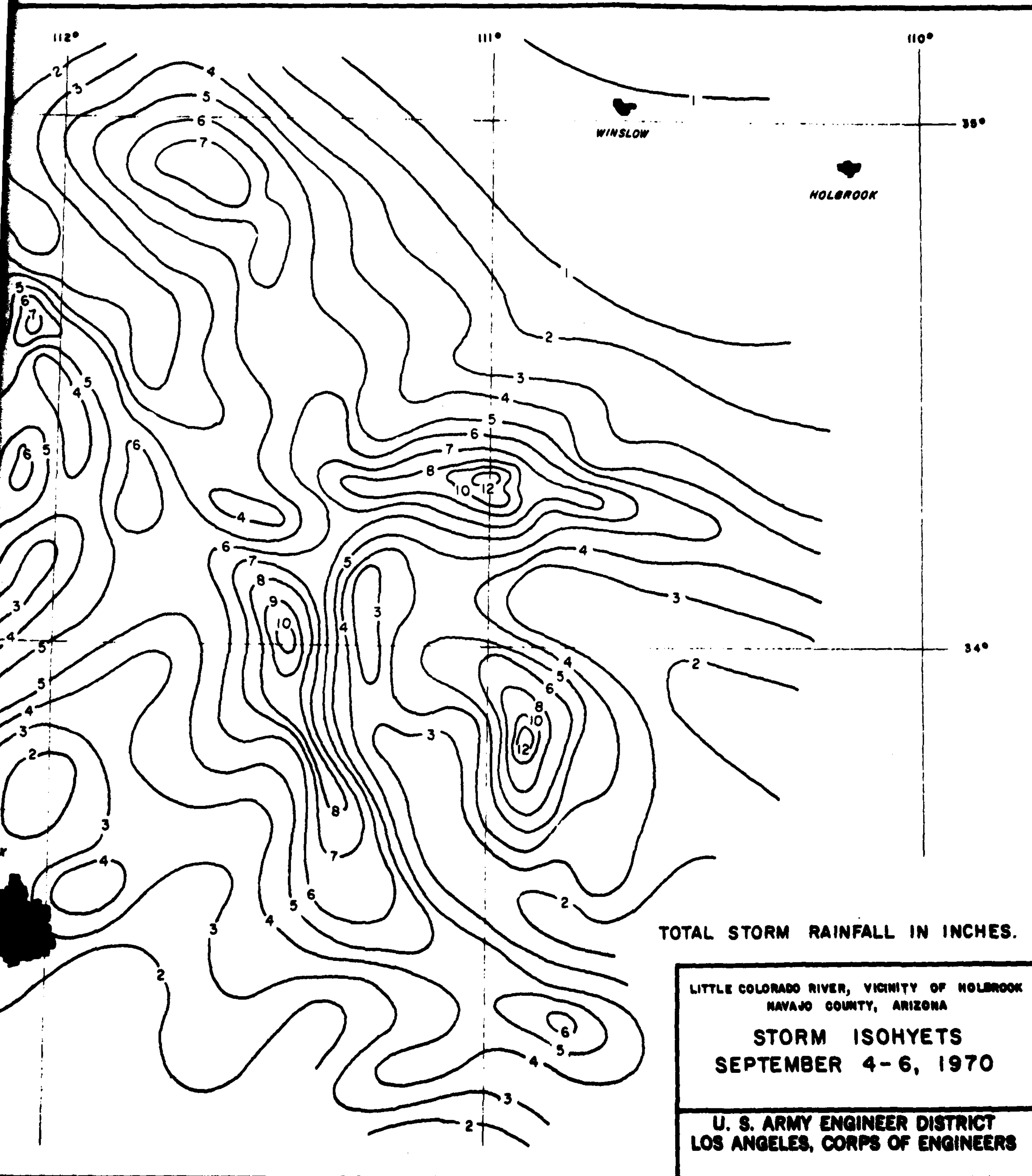
LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

DISCHARGE HYDROGRAPH OF RECORDED FLOOD

OCTOBER 19-21, 1972

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS


113°
112°
10 0 10 20 30 Miles
PRESCOTT
PHOENIX

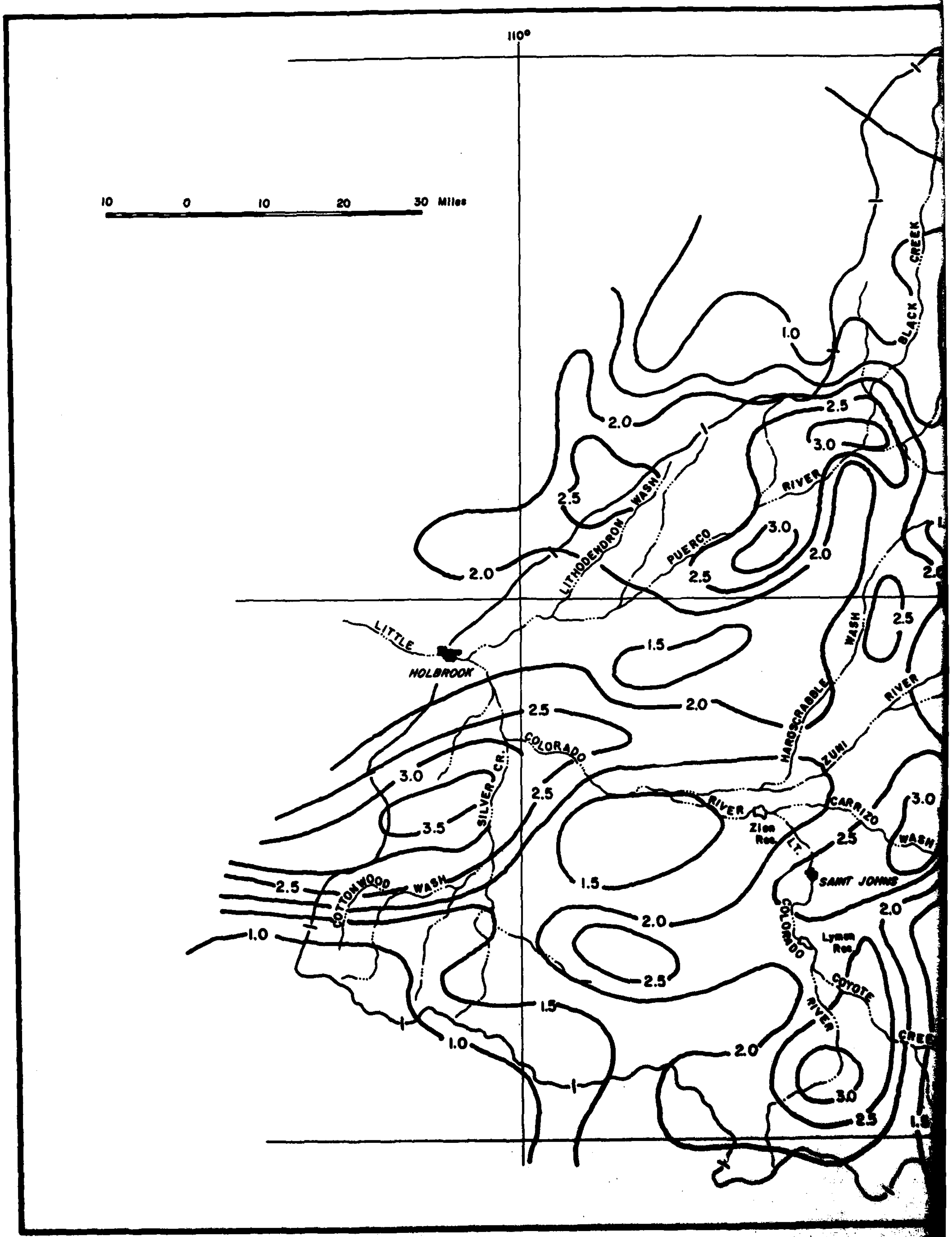


LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

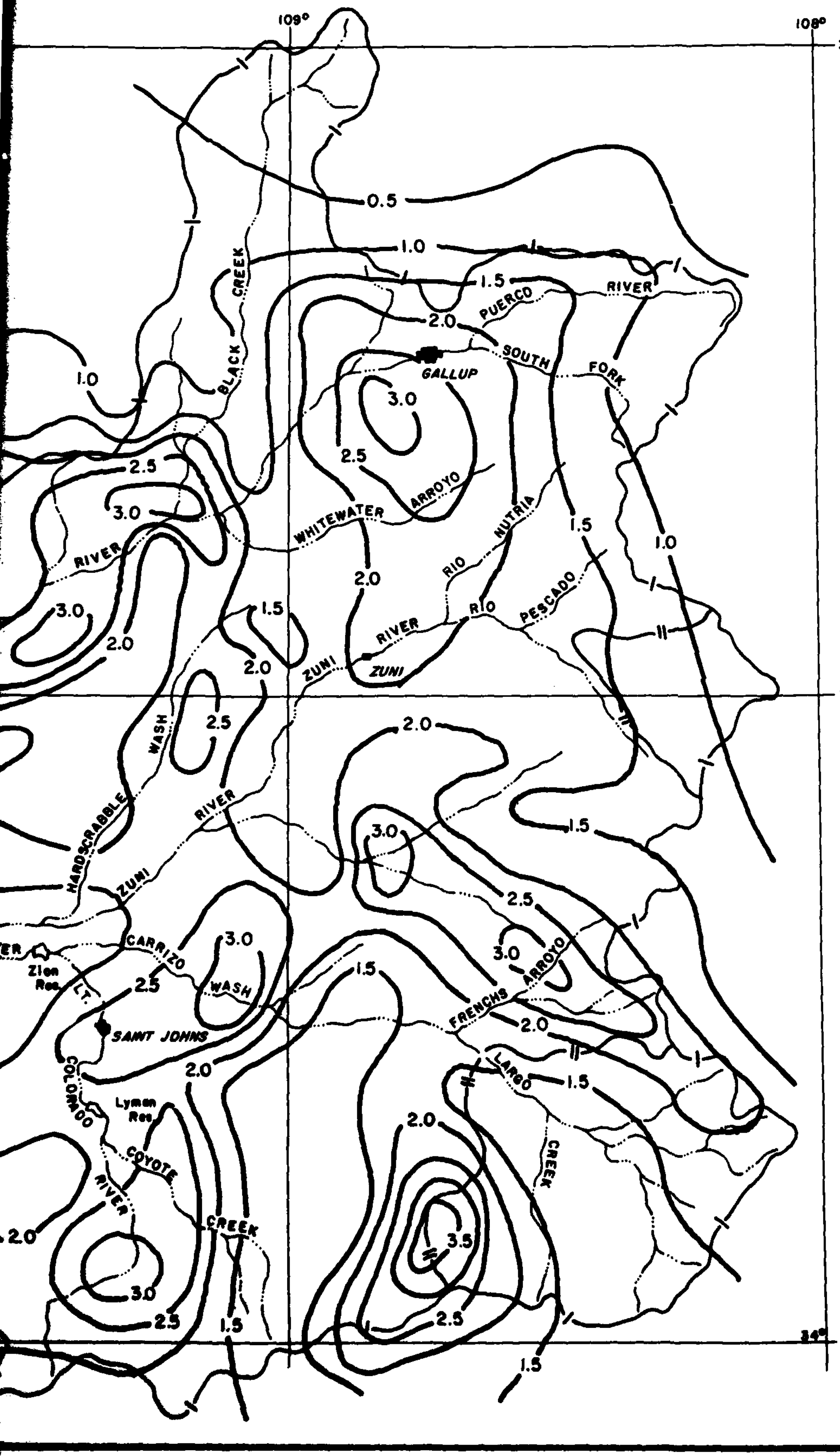
STORM ISOHYETS
SEPTEMBER 4-6, 1970

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE F-9



110°
10 0 10 20 30 Miles
1.0
2.0
2.5
3.0
BLACK CREEK
RIVER
LITHODENDRON WASH
PUERCO
LITTLE
HOLBROOK
1.5
HARDSCRABBLE WASH
RIVER
ZUNI
COLORADO
SILVER CR.
3.5
RIVER
Zion Res.
CARRIZO WASH
LT. COLORADO
SAINT JOHNS
COTTONWOOD WASH
Lyman Res.
COYOTE CREEK
RIVER



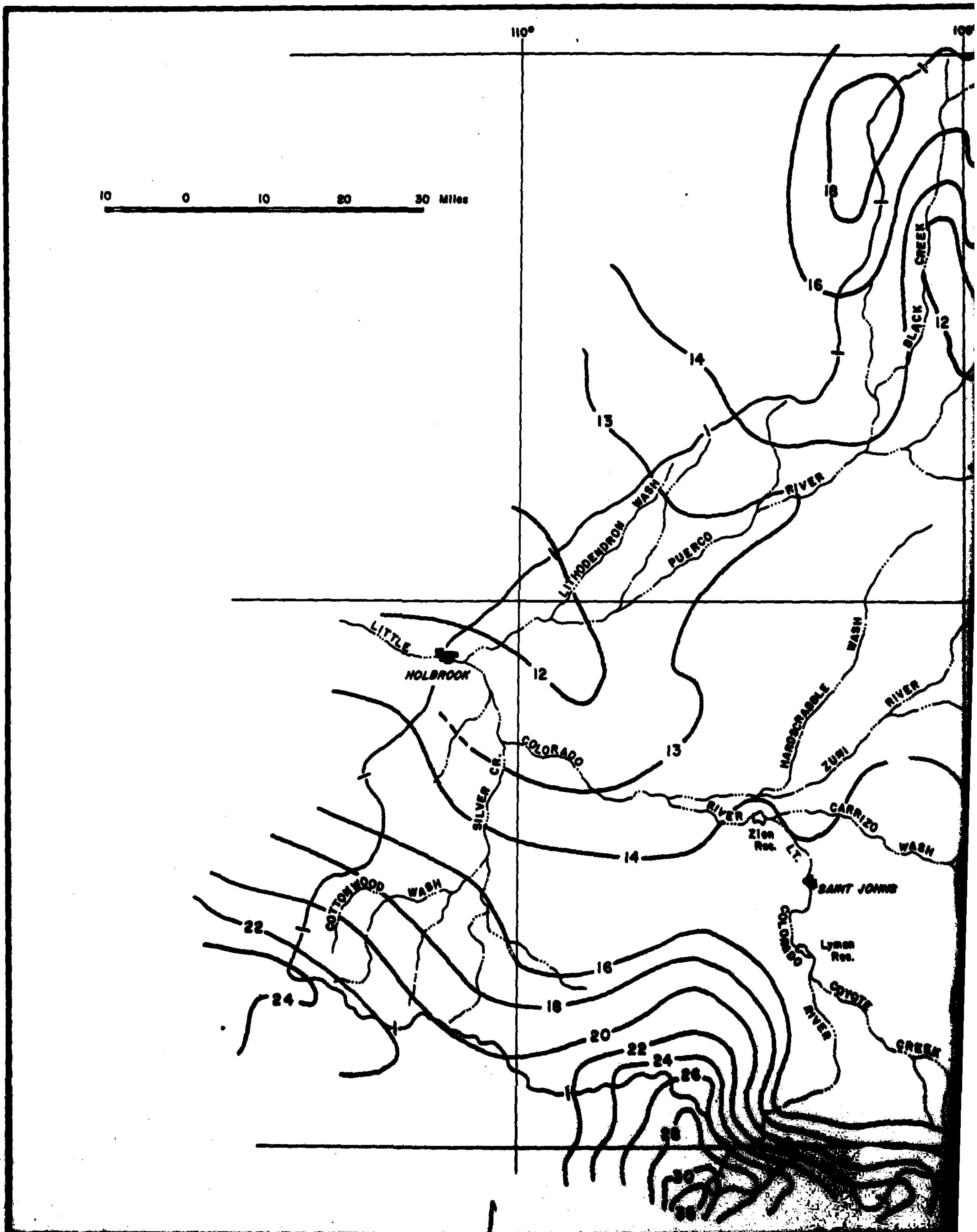
ISOPERCENTUALS OF 2-YR 24-HR CENTERED FOR MAXIMUM AT HOLBROOK.

LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

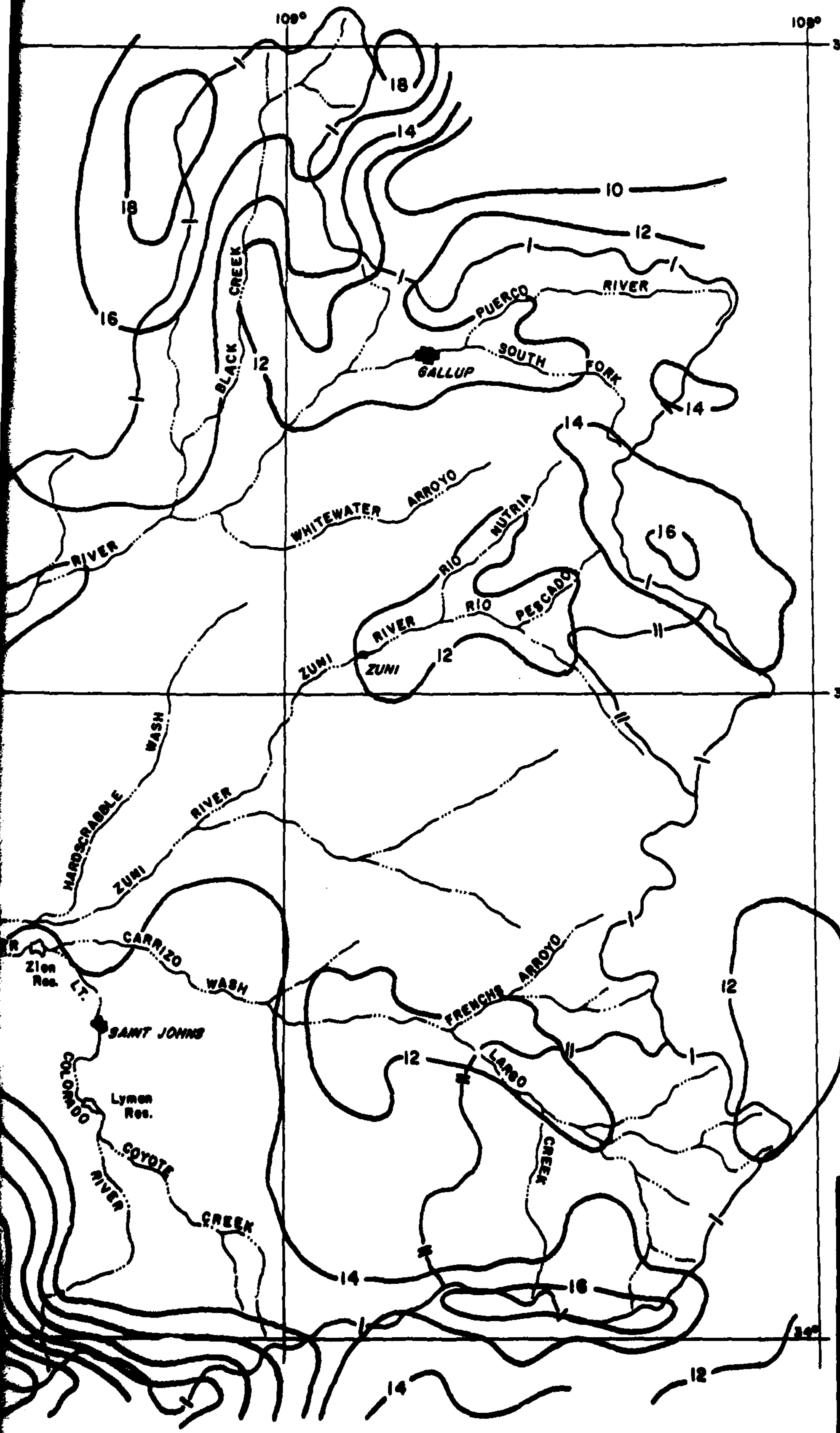
ISOPERCENTUAL MAP

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE F-10



110°
109°
10 0 10 20 30 Miles
18
16
14
13
12
BLACK CREEK
LITHODENDRON WASH
PUERCO RIVER
LITTLE
HOLBROOK
COLORADO
SILVER CR.
HARDSCRABBLE WASH
ZUNI RIVER
RIVER
Zion Res.
CARRIZO WASH
LT.
SAINT JOHNS
COLORADO RIVER
Lyman Res.
COYOTE CREEK
COTTONWOOD WASH
22
24
20
26
28
30



ISOPLUVIALS OF 2-YR 24-HR PRECIPITATION IN TENTHS OF AN INCH.

LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

PRECIPITATION - FREQUENCY MAP

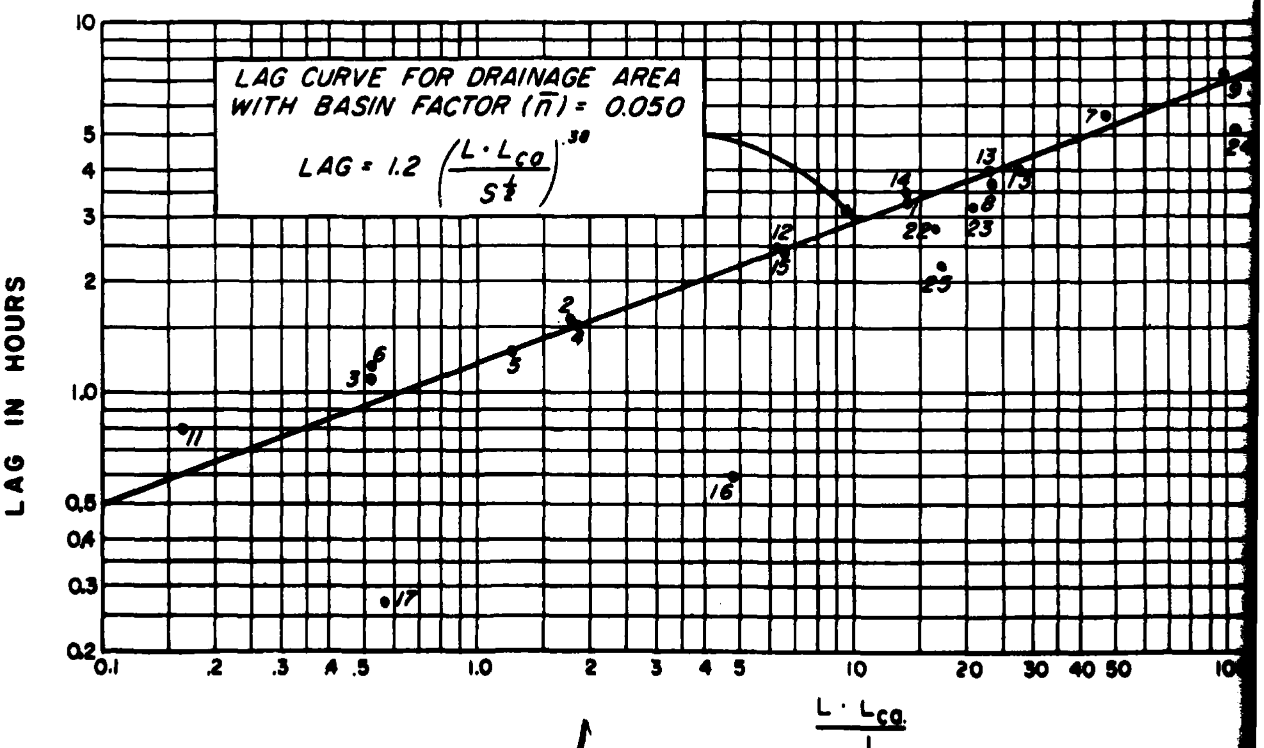
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE F-11.

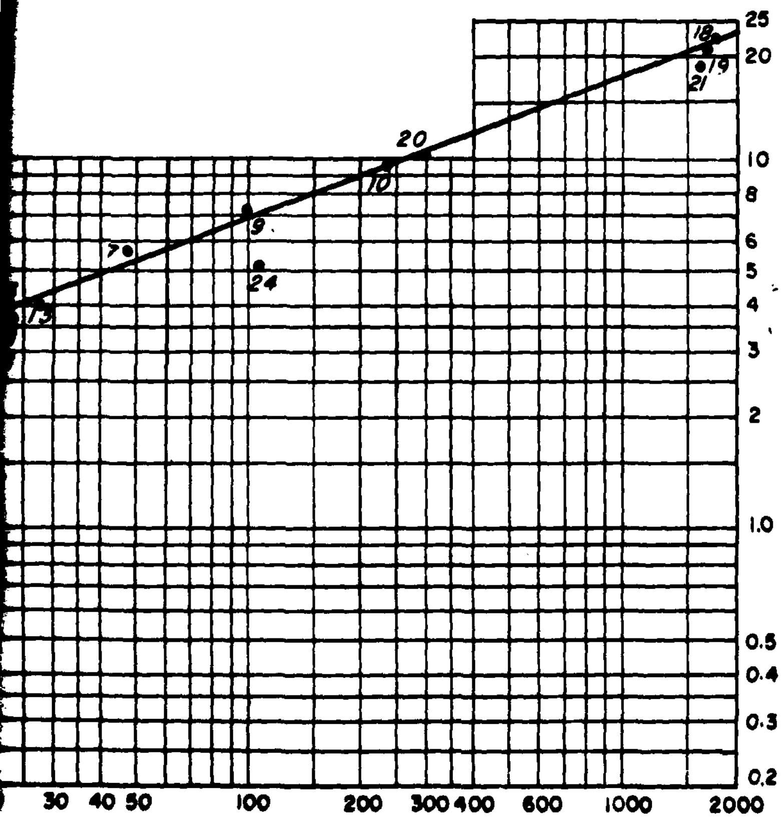
1

2

		CONTRIBUTING AREA SQ. MI.	L MILES	L_{ca} MILES	S FT/MI.
1.	SAN GABRIEL RIVER AT SAN GABRIEL DAM, CALIF.	162.0	23.2	11.6	350
2.	WEST FORT SAN GABRIEL RIVER AT COGSWELL DAM, CALIF.	40.4	9.3	4.3	450
3.	SAN ANITA CREEK AT SANTA ANITA DAM, CALIF.	10.8	5.8	2.5	690
4.	SAN DIMAS CREEK AT SAN DIMAS DAM, CALIF.	16.2	8.6	4.8	440
5.	EATON WASH AT EATON WASH DAM, CALIF.	9.5	7.3	4.4	600
6.	SAN ANTONIO CREEK NEAR CLAREMONT, CALIF.	16.9	5.9	3.0	1,017
7.	SANTA CLARA RIVER NEAR SAUGUS, CALIF	355.0	36.0	15.8	140
8.	TEMECULA CREEK AT PAUBA CANYON, CALIF.	168.0	26.0	11.3	150
9.	SANTA MARGARITA RIVER NEAR FALLBROOK, CALIF.	645.0	46.0	22.0	105
10.	SANTA MARGARITA RIVER AT YSIDORA, CALIF.	740.0	61.2	34.3	85
11.	LIVE OAK CREEK AT LIVE OAK DAM, CALIF.	2.3	2.9	1.5	700
12.	TUJUNGA CREEK AT BIG TUJUNGA DAM, CALIF.	81.4	15.1	7.3	290
13.	MURRIETA CREEK AT TEMECULA, CALIF.	220.0	27.2	10.3	95
14.	LOS ANGELES RIVER AT SEPULVEDA DAM, CALIF.	152.0	19.0	9.0	145
15.	PACOIMA WASH AT PACOIMA DAM, CALIF.	27.8	15.0	8.0	315
16.	ALHAMBRA WASH ABOVE SHORT STREET, CALIF.	14.0	9.5	4.6	85
17.	BROADWAY DRAIN ABOVE RAYMOND DIKE, CALIF.	2.5	3.4	1.7	100
18.	GILA RIVER AT CONNOR NO. 4 DAM SITE, ARIZ.	2840.0	131.0	71.0	29
19.	SAN FRANCISCO RIVER AT JUNCTION WITH BLUE RIVER, ARIZ.	2000.0	130.0	74.0	32
20.	BLUE RIVER NEAR CLIFTON, ARIZ	790.0	77.0	37.0	65
21.	SALT RIVER NEAR ROOSEVELT, ARIZ.	4310.0	160.0	66.0	45
22.	NEW RIVER AT ROCK SPRINGS, ARIZ.	67.3	20.2	9.7	141
23.	NEW RIVER AT NEW RIVER, ARIZ.	85.7	26.2	8.9	122
24.	NEW RIVER AT BELL ROAD, ARIZ.	187.0	47.6	20.7	83
25.	SKUNK CREEK NEAR PHOENIX, ARIZ.	64.6	17.6	9.9	102



L_{ca}	S	LAG	ESTIMATED $\bar{n}$
MILES	FT./MI.	HOURS	
11.6	350	3.3	0.050
4.3	450	1.6	.050
2.5	690	1.1	.050
4.8	440	1.5	.050
4.4	600	1.3	.050
3.0	1,017	1.2	.055
15.8	140	5.6	.050
11.3	150	3.7	.050
22.0	105	7.3	.055
34.3	85	9.5	.055
1.5	700	8	.070
7.3	290	2.5	.050
10.3	95	4.0	.050
9.0	145	3.5	.050
8.0	315	2.4	.050
4.6	85	.6	.015
1.7	100	.28	.015
71 0	29	21.5	.050
74 0	32	20.6	.050
37.0	65	10.3	.050
66.0	45	18.6	.050
9.7	141	2.8	.044
8 9	122	3.2	.042
20.7	83	5.1	.035
9.9	102	2.3	.031



GUIDE FOR ESTIMATING BASIN FACTOR ($\bar{n}$)

$\bar{n}$=0.200: DRAINAGE AREA HAS COMPARATIVELY UNIFORM SLOPES AND SURFACE CHARACTERISTICS SUCH THAT CHANNELIZATION DOES NOT OCCUR. GROUND COVER CONSISTS OF CULTIVATED CROPS OR SUBSTANTIAL GROWTHS OF GRASS AND FAIRLY DENSE SMALL SHRUBS, CACTI, OR SIMILAR VEGETATION. NO DRAINAGE IMPROVEMENTS EXIST IN THE AREA.

$\bar{n}$=0.050: DRAINAGE AREA IS QUITE RUGGED, WITH SHARP RIDGES AND NARROW, STEEP CANYONS THROUGH WHICH WATERCOURSES MEANDER AROUND SHARP BENDS, OVER LARGE BOULDERS, AND CONSIDERABLE DEBRIS OBSTRUCTION. THE GROUND COVER, EXCLUDING SMALL AREAS OF ROCK OUTCROPS, INCLUDES MANY TREES AND CONSIDERABLE UNDERBRUSH. NO DRAINAGE IMPROVEMENTS EXIST IN THE AREA.

$\bar{n}$=0.030: DRAINAGE AREA IS GENERALLY ROLLING, WITH ROUNDED RIDGES AND MODERATE SIDE SLOPES. WATERCOURSES MEANDER IN FAIRLY STRAIGHT, UNIMPROVED CHANNELS WITH SOME BOULDERS AND LODGED DEBRIS. GROUND COVER INCLUDES SCATTERED BRUSH AND GRASSES. NO DRAINAGE IMPROVEMENTS EXIST IN THE AREA.

$\bar{n}$=0.015: DRAINAGE AREA HAS FAIRLY UNIFORM, GENTLE SLOPES WITH MOST WATERCOURSES EITHER IMPROVED OR ALONG PAVED STREETS. GROUND COVER CONSISTS OF SOME GRASSES WITH APPRECIABLE AREAS DEVELOPED TO THE EXTENT THAT A LARGE PERCENTAGE OF THE AREA IS IMPERVIOUS.

TERMINOLOGY

L = LENGTH OF LONGEST WATERCOURSE.

L_{ca} = LENGTH ALONG LONGEST WATERCOURSE, MEASURED UPSTREAM TO POINT OPPOSITE CENTER OF AREA.

S = OVER-ALL SLOPE OF LONGEST WATERCOURSE BETWEEN HEADWATER AND COLLECTION POINT.

LAG = ELAPSED TIME FROM BEGINNING OF UNIT PRECIPITATION TO INSTANT THAT SUMMATION HYDROGRAPH REACHES 50 % OF ULTIMATE DISCHARGE.

$\bar{n}$ = VISUALLY ESTIMATED MEAN OF THE n (MANNING'S FORMULA) VALUES OF ALL THE CHANNELS WITHIN AN AREA.

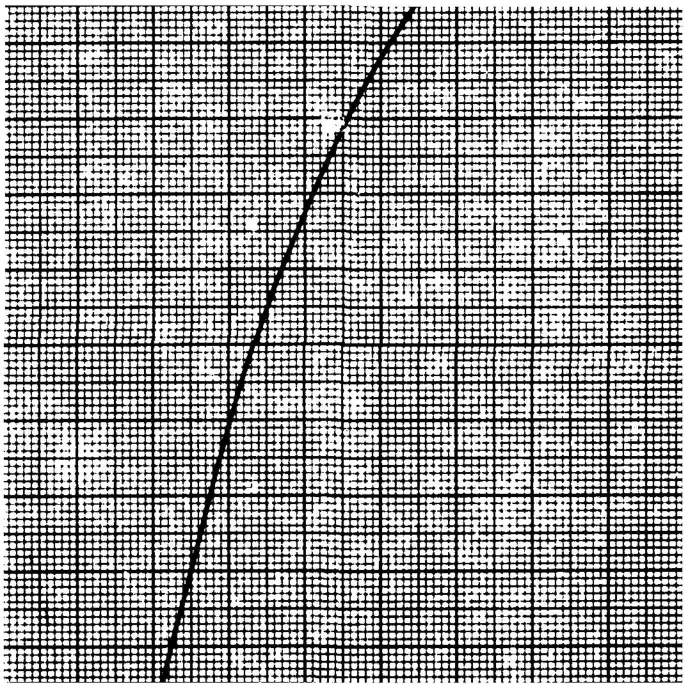
NOTE:
TO OBTAIN THE LAG (IN HOURS) FOR ANY AREA, MULTIPLY THE LAG OBTAINED FROM THE CURVE BY:

$$\frac{\bar{n}}{0.050} \text{ OR } 20\bar{n}$$

LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

LAG RELATIONSHIPS

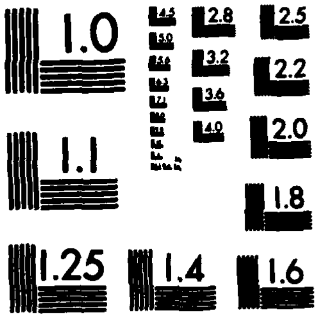
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS



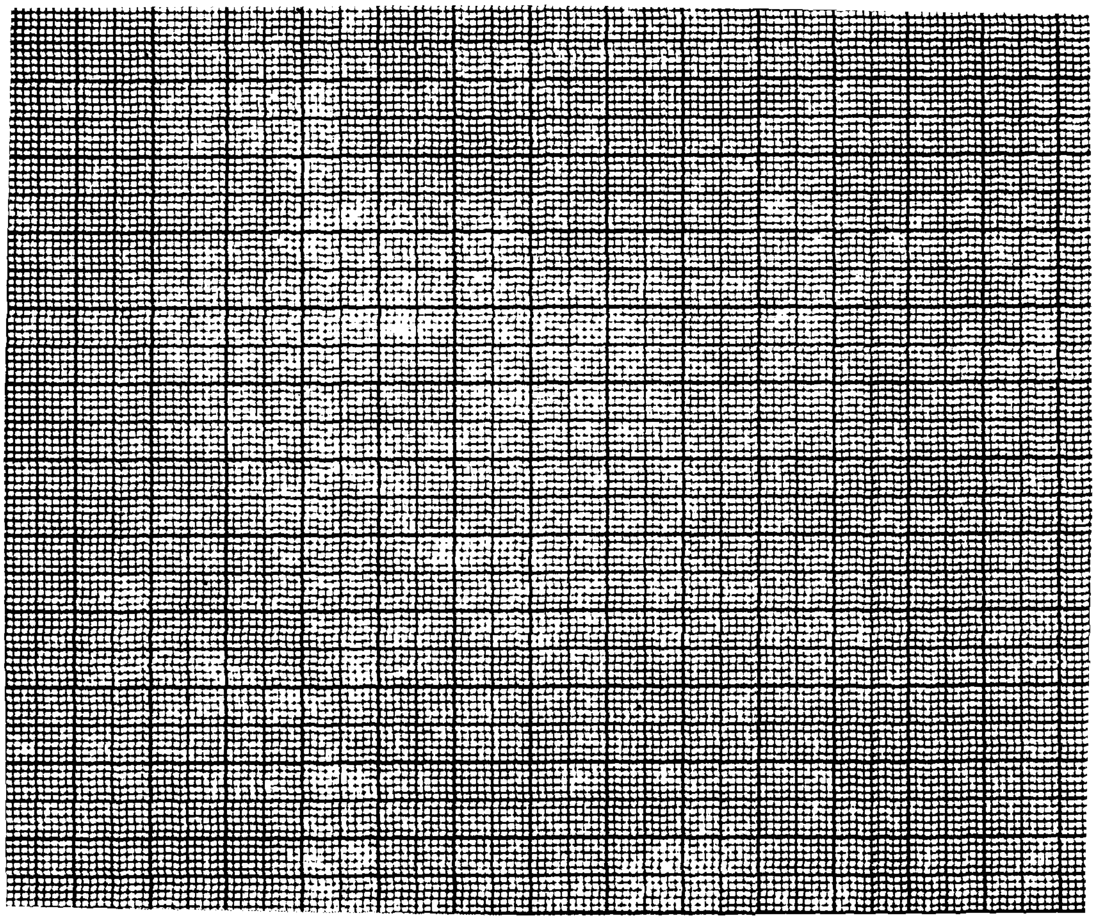
AD-A136 661 REVIEW REPORT FOR FLOOD CONTROL AND RECREATIONAL DEVELOPMENT LITTLE COLOR..(U) ARMY ENGINEER DISTRICT LOS ANGELES CA SEP 80 4/4

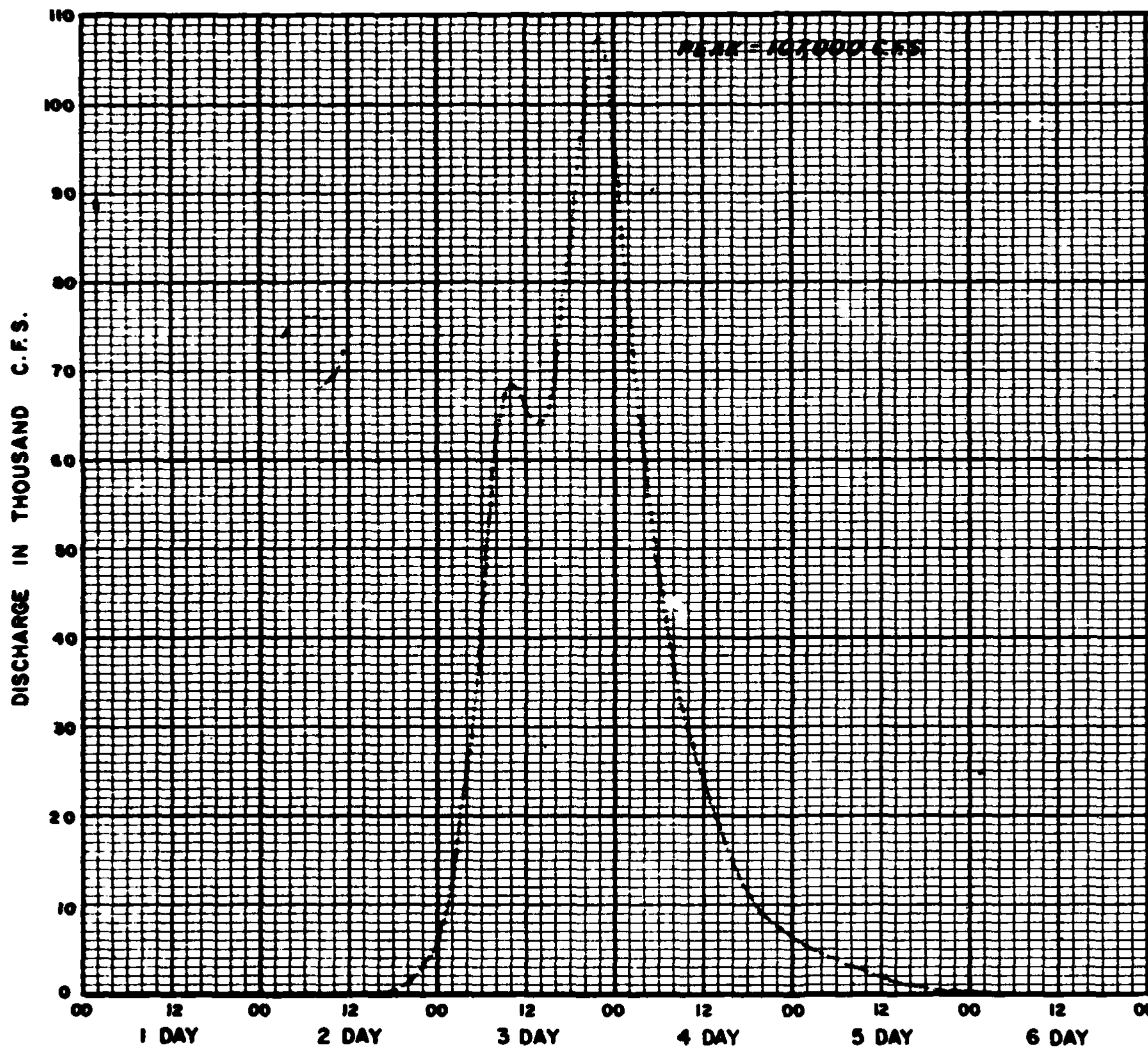
UNCLASSIFIED F/G 13/2 NL

END
DATE
FILMED
2-84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A





LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

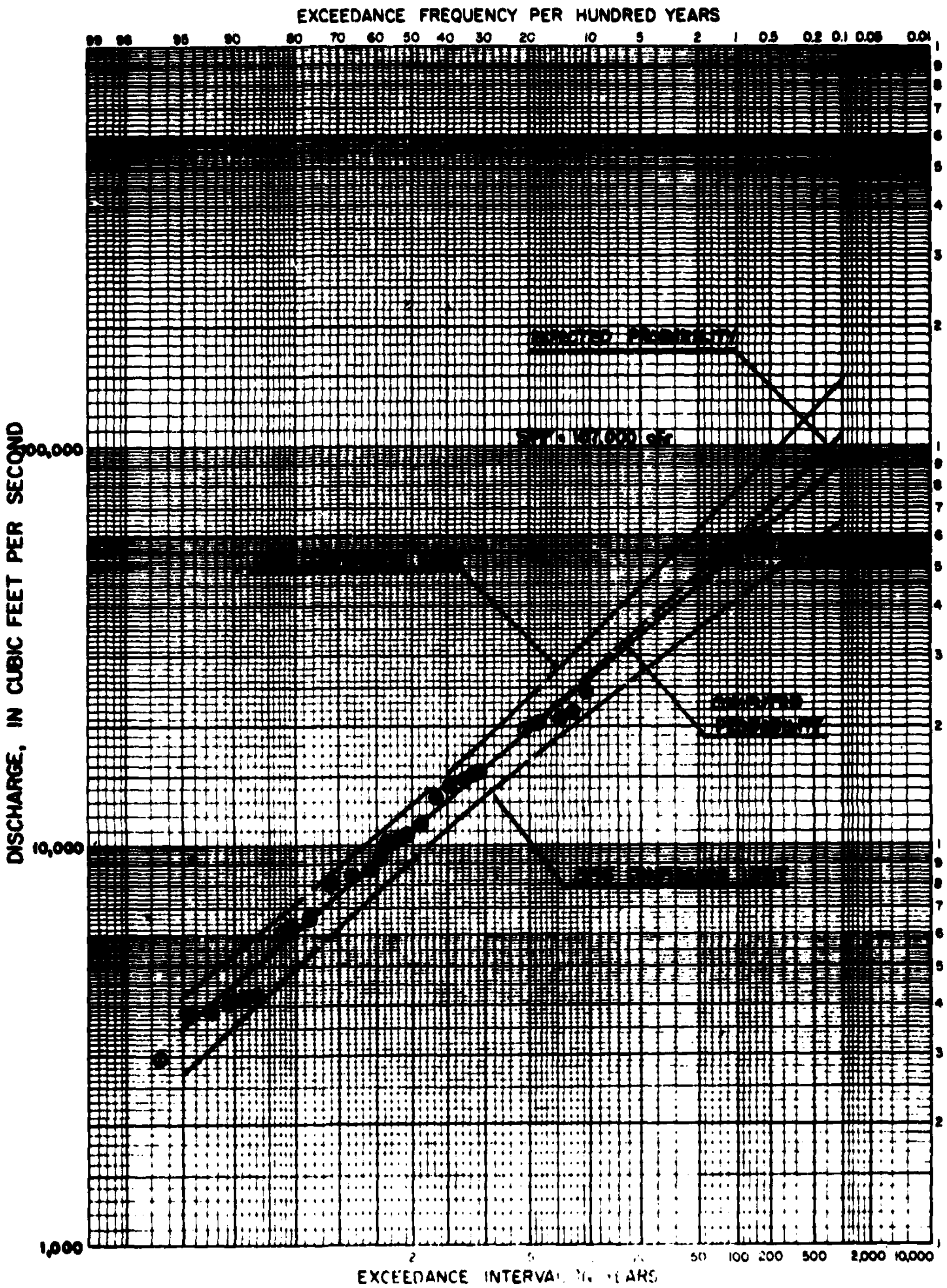
Standard Project Flood

HYDROGRAPH

Little Colorado River
at Holbrook

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE F-14



MEAN 4.038
STD. DEV. 0.297
COMPUTED SKEW 0.044
GENERALIZED SKEW (Bulletin 17) 0.0
ADOPTED SKEW 0.0

⊡ 1923 FLOOD PEAK, REPORTED TO BE LARGEST SINCE 1870.

● MEDIAN PLOTTING POSITIONS N = 27 YEARS, H = 107 YEARS

LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

DISCHARGE-FREQUENCY CURVE

LITTLE COLORADO RIVER AT HOLBROOK, AZ.

USGS GAGE# 09397000 DA = 11,300 SQ.MI.

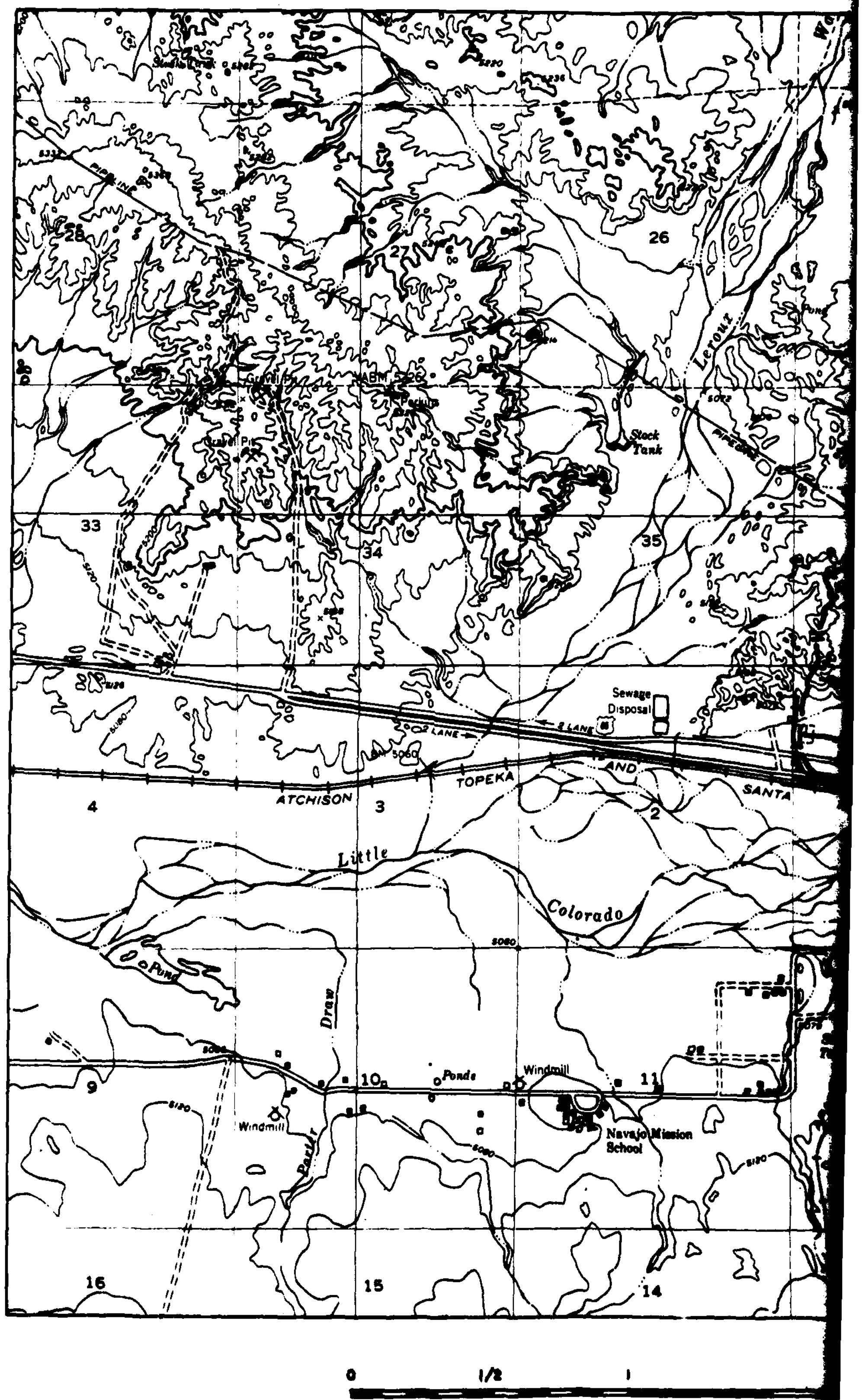
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT
TO ACCOMPANY REPORT DATED

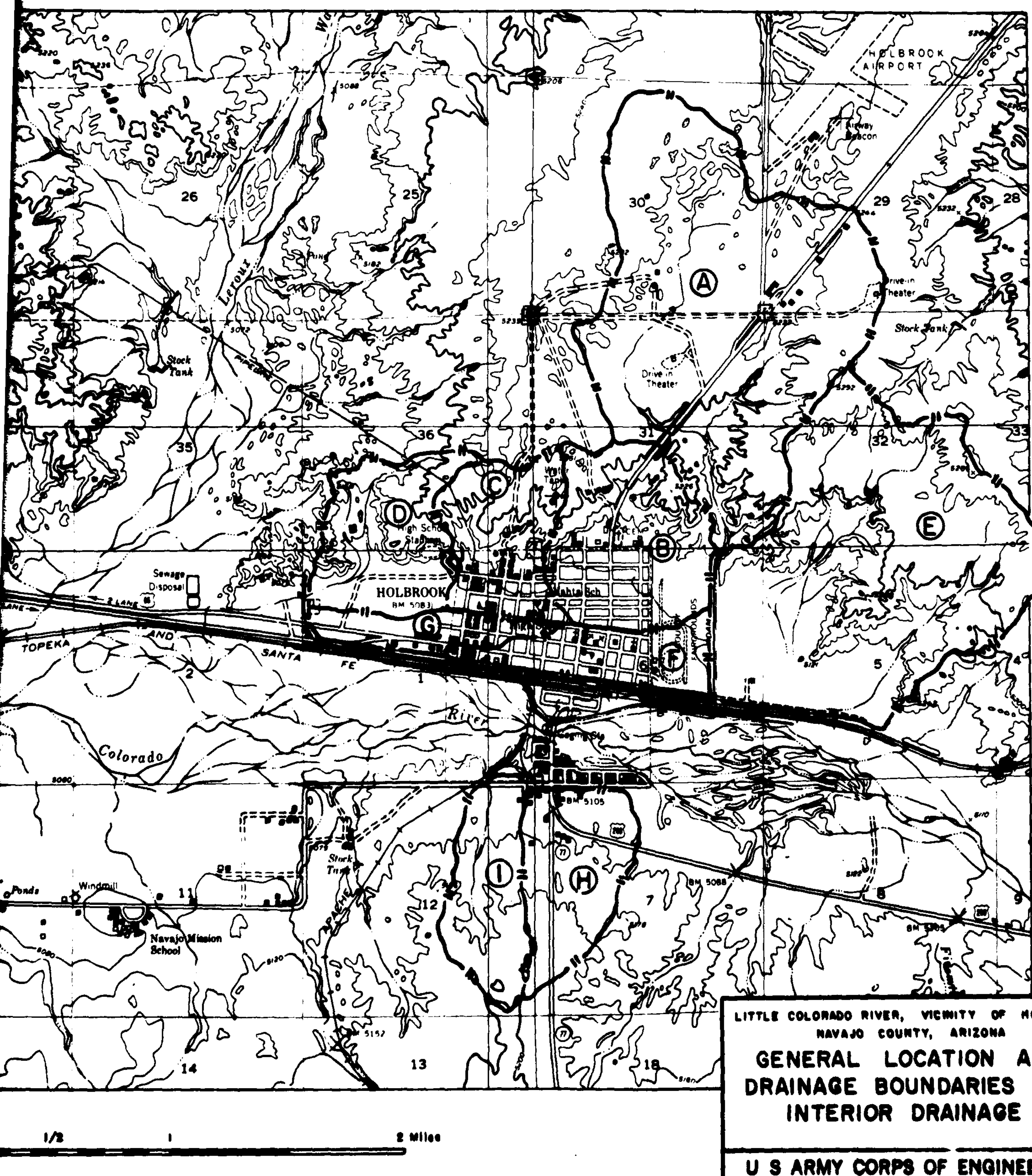
PLATE F-15

LEGEND

SUBAREA BOUNDARY

SUBAREA DESIGNATION Ⓐ



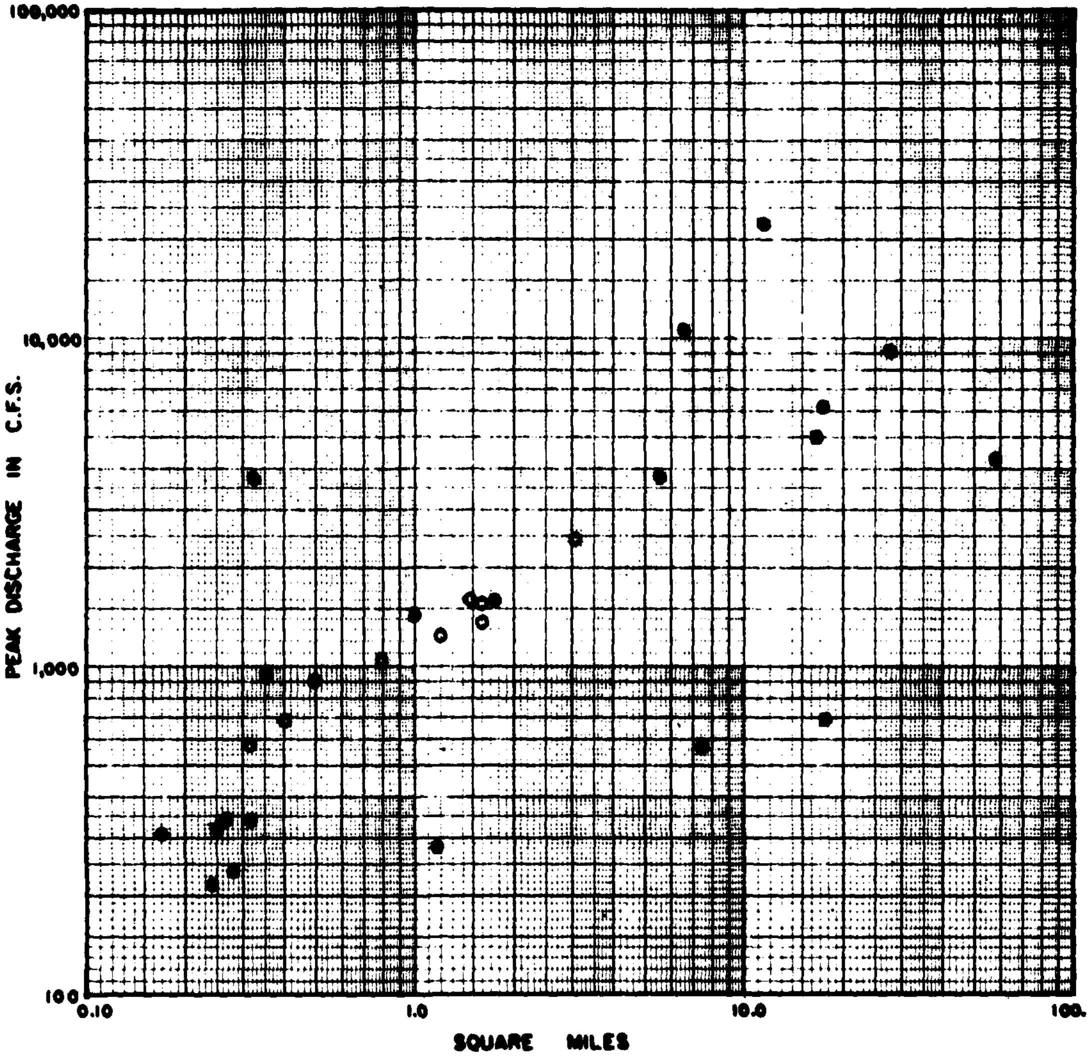


LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

GENERAL LOCATION AND DRAINAGE BOUNDARIES FOR INTERIOR DRAINAGE

U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE F-16



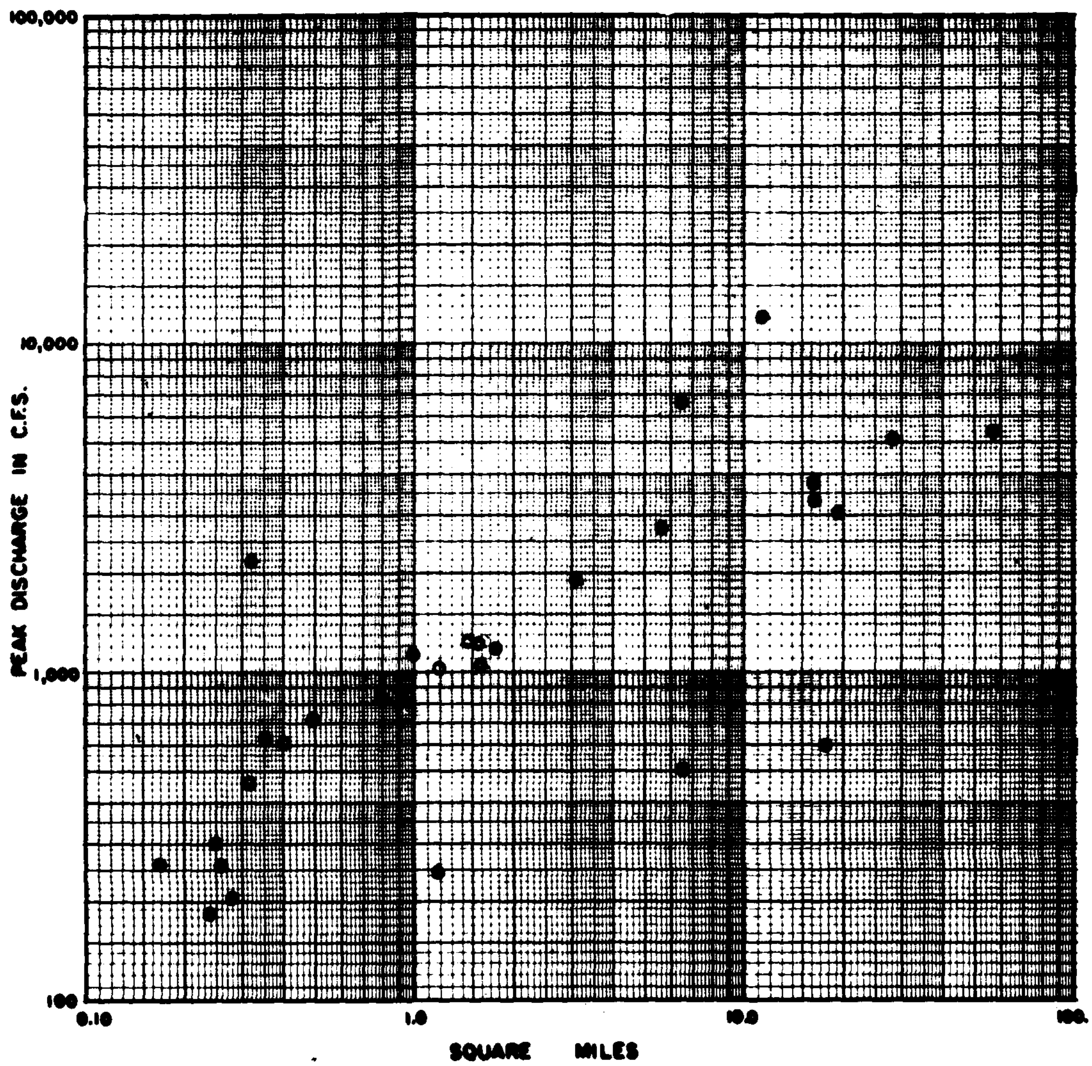
● Crest-Stage Gaging Station
o Interior Drainage Concentration Point

LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

RELATIONSHIP OF 100-YEAR FLOOD PEAK DISCHARGE TO DRAINAGE AREA SIZE

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE F-17



● Crest-Stage Gaging Station

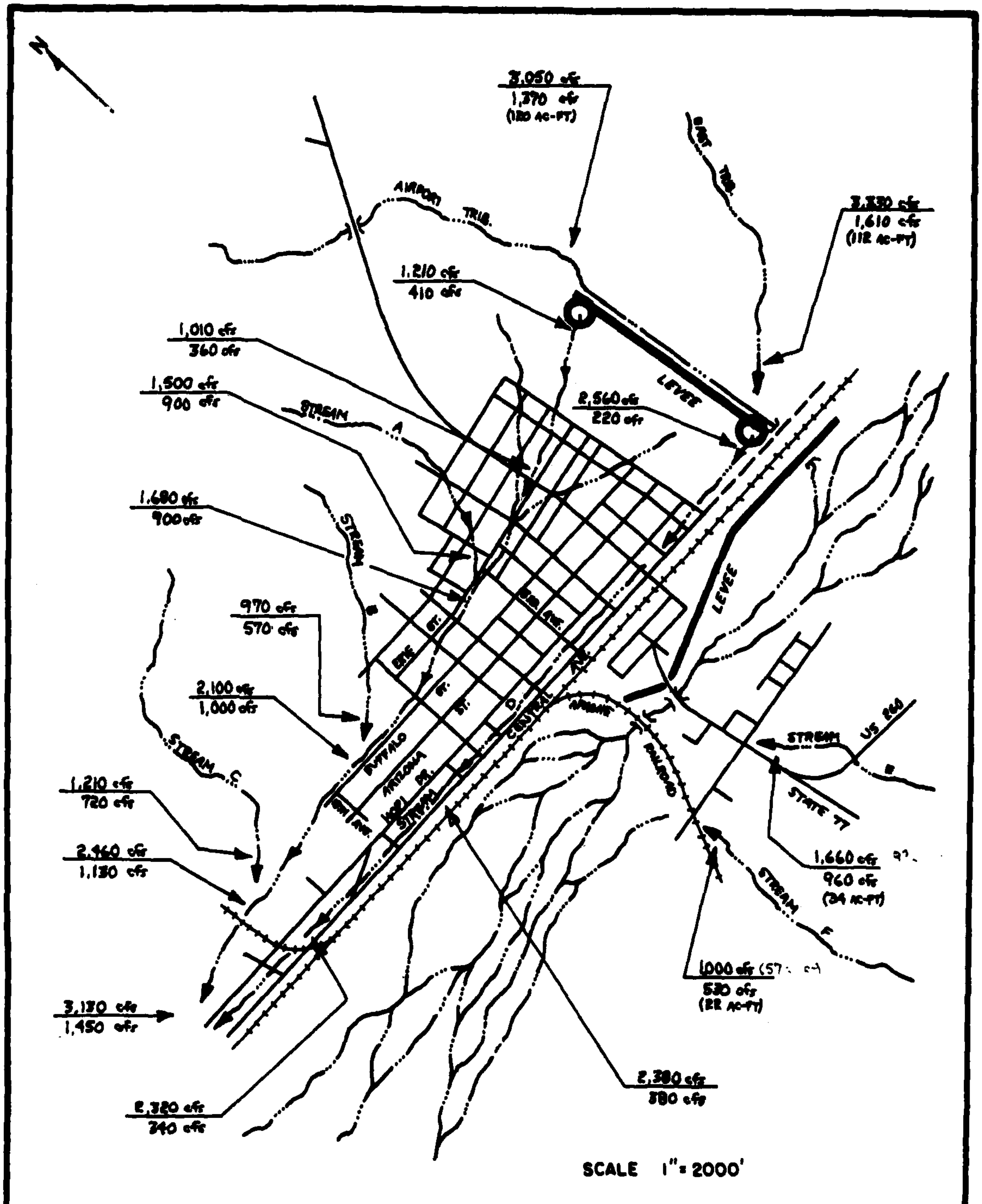
○ Interior Drainage Concentration Point

LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

RELATIONSHIP OF 50-YEAR FLOOD PEAK DISCHARGE TO DRAINAGE AREA SIZE

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE F-18



BREAKOUT AREA

STANDARD PROJECT FLOOD
100-YEAR FLOOD
(100-YEAR VOLUME)*

* AT CERTAIN CP'S

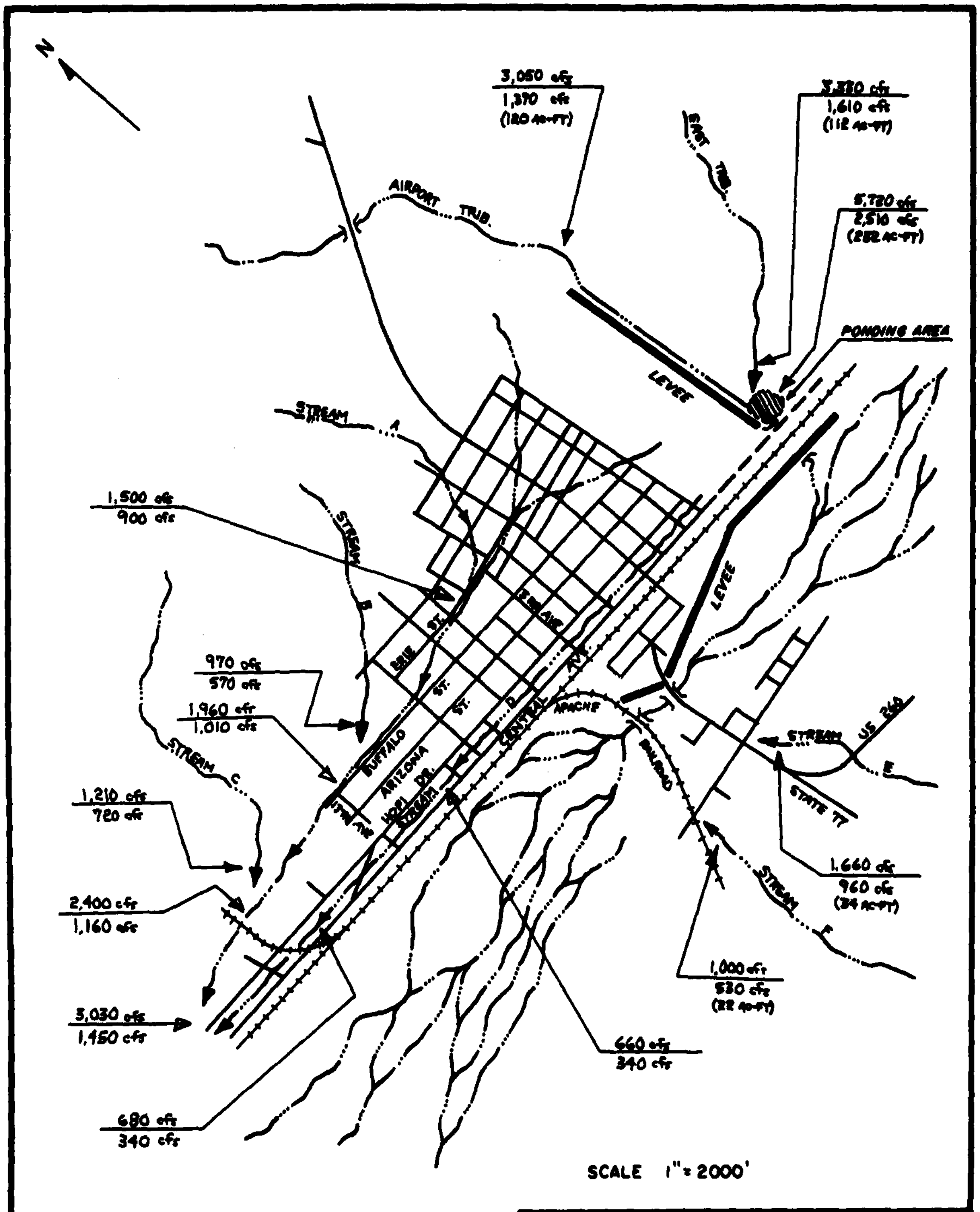
LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

PEAK FLOWS FOR INTERIOR DRAINAGE

NON-PROJECT CONDITIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE F-19



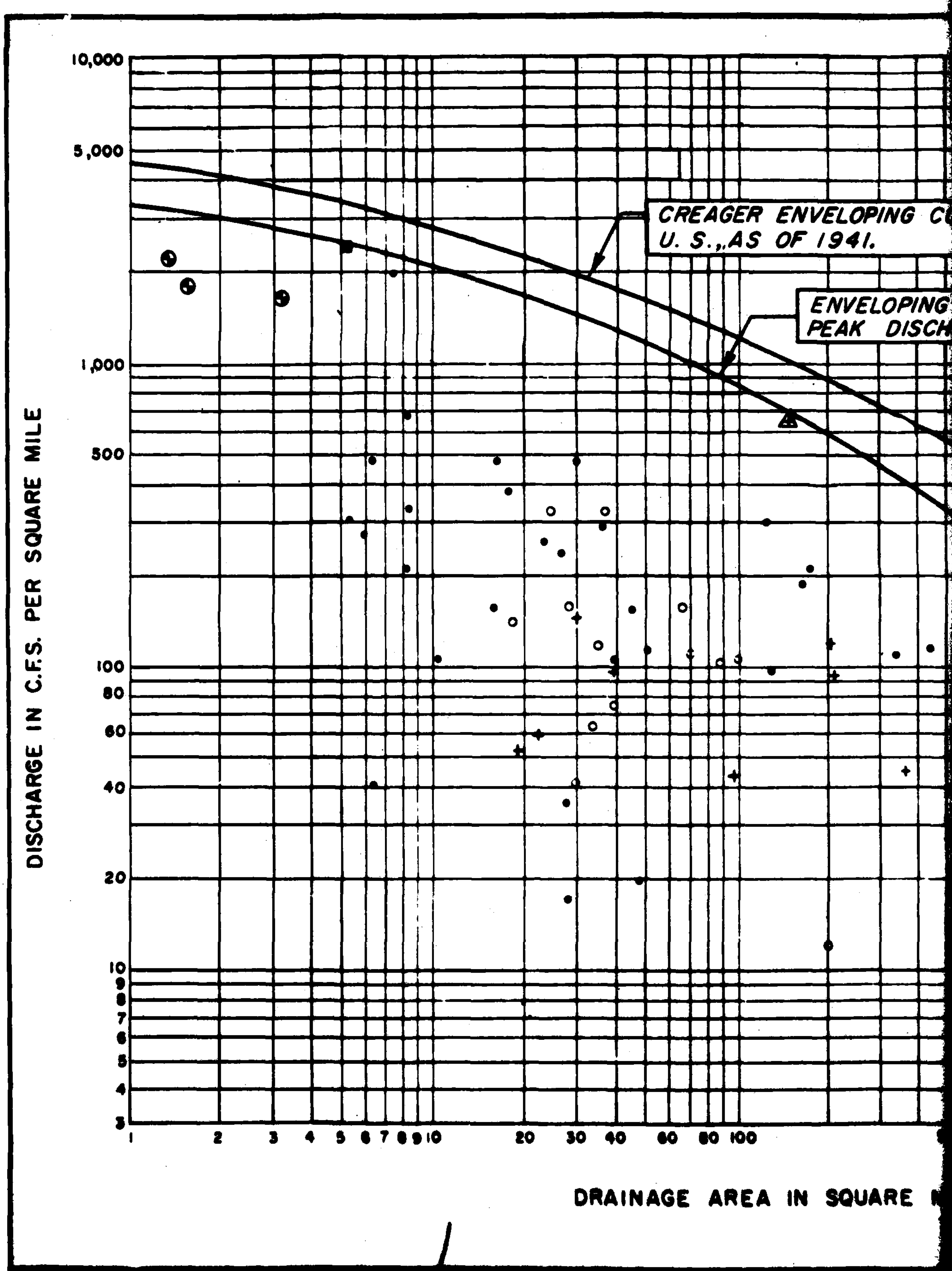
LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

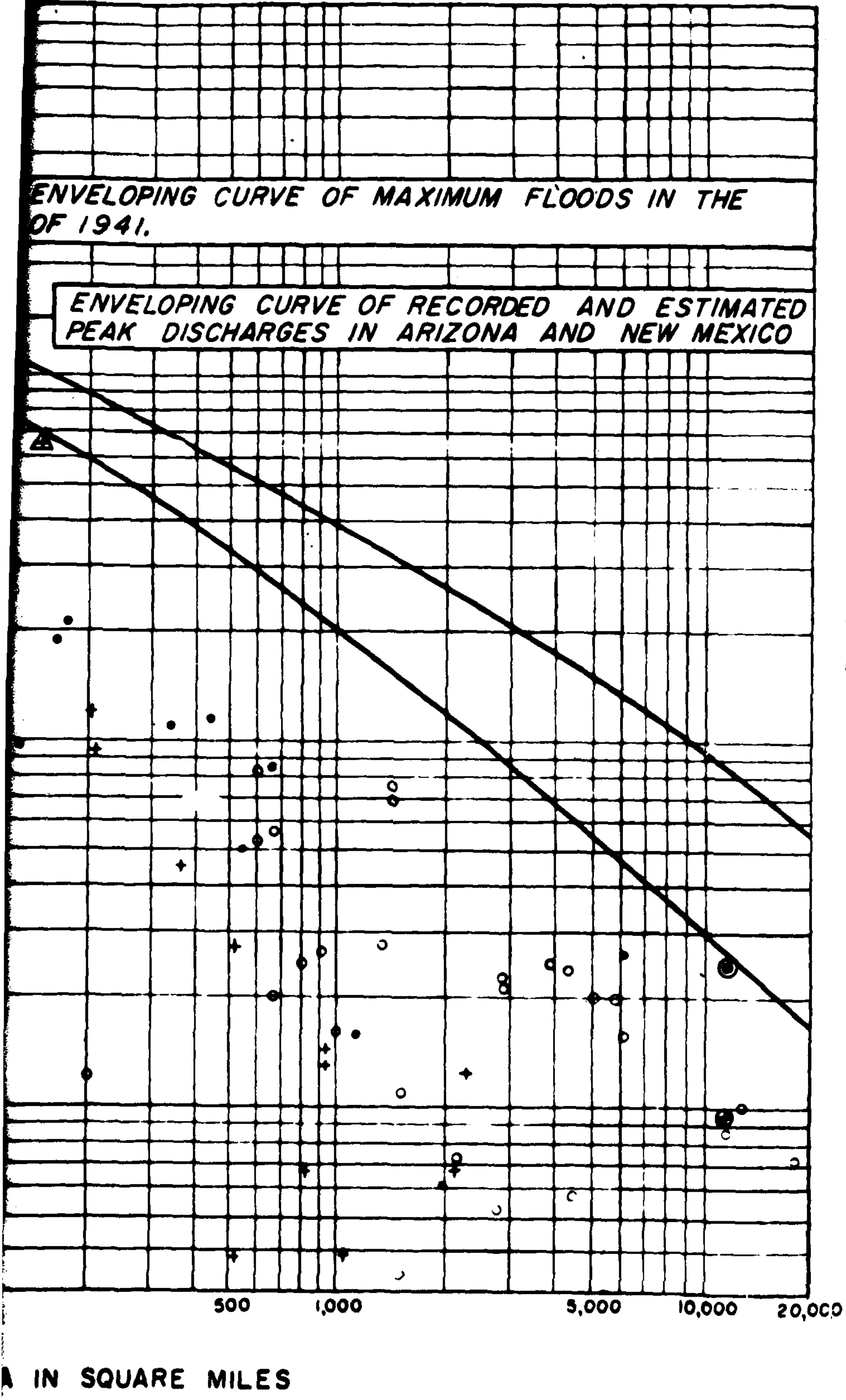
PEAK FLOWS FOR INTERIOR DRAINAGE

PROJECT CONDITIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE F-20


CREAGER ENVELOPING C
U. S., AS OF 1941.
ENVELOPING
PEAK DISCH
DISCHARGE IN C.F.S. PER SQUARE MILE
10,000
5,000
1,000
500
100
80
60
40
20
10
9
8
7
6
5
4
3
1
2
3
4
5
6
7
8
9
10
20
30
40
60
80
100
DRAINAGE AREA IN SQUARE



LEGEND

- ○ FLOODS FROM GENERAL RAIN OR SNOW MELT RUNOFF.
- ✛ FLOODS FROM LOCAL SUMMER STORMS.
- • FLOOD TYPE UNDETERMINED.
- ▪ ALDER CREEK AT MOUTH-LOCAL STORM.
- ▲ BEAR CREEK AT MOUTH-LOCAL STORM.
- ◉ SALT RIVER AT GRANITE REEF DAM – GENERAL STORM.
- ⊛ STANDARD PROJECT FLOOD. LITTLE COLORADO RIVER AT HOLBROOK.

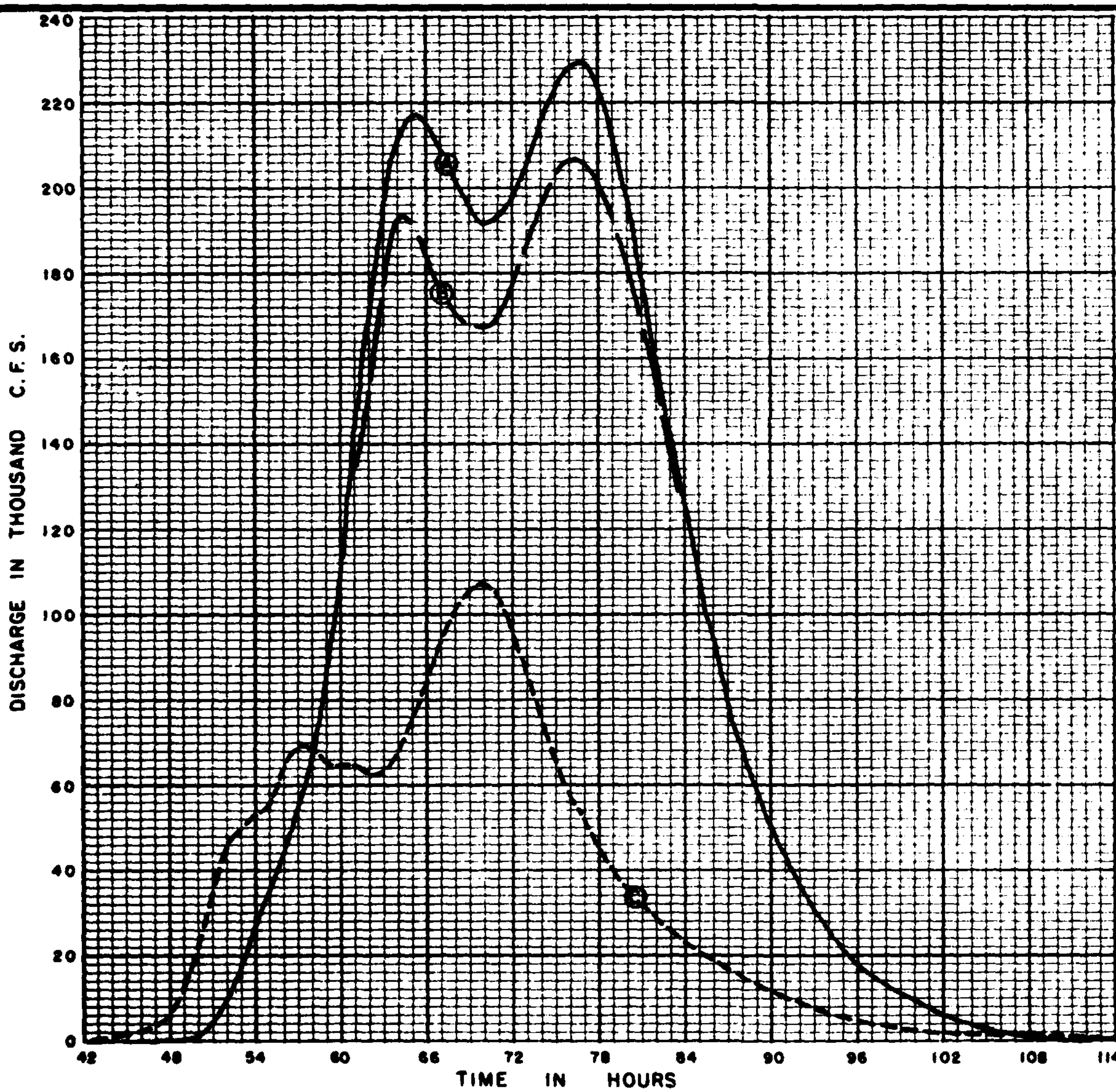
LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

ENVELOPING CURVES OF PEAK DISCHARGES

STREAMS IN ARIZONA AND NEW MEXICO

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE F-21



PROBABLE MAXIMUM FLOOD:

5,000 sq. mi. Areal Reduction Ⓐ

11,300 sq. mi. Areal Reduction Ⓑ

STANDARD PROJECT FLOOD Ⓒ

LITTLE COLORADO RIVER, VICINITY OF HOLBROOK
NAVAJO COUNTY, ARIZONA

COMPARISON OF HYDROGRAPHS

LITTLE COLORADO at HOLBROOK

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

APPENDIX

Contents

Little Colorado River
Holbrook, Arizona

Geotechnical Appendix

Amendment 1

Purpose. The purpose of this amendment is to supplement the Little Colorado River, Holbrook, Arizona, Geotechnical Appendix. The 1945 soils log and laboratory test information was not included in the initial report, although it was refered to. This amendment presents the existing borrow area information.

Amendment. Under the heading, Construction Materials, delete paragraph 10 and insert the following:
"10. Borrow Areas: Sufficient quantities of borrow materials may be obtained from designated borrow areas along the northern foothills bordering Holbrook, see Plate 1. Borrow site investigations, conducted in the project area, for the original Little Colorado River levee project by the Los Angeles District in 1945, indicate layers of clayey silt and silty sand, overlain by a layer of gravel along the northwest foothills. See Plates 1 through 7 for location and laboratory test information. A similar soil profile is expected in the designated borrow areas. Native streambed materials consisting mainly of fine uncompacted alluvial sands are unsuitable for use in construction of the levee. See Plate 8. Pending further site investigations, materials from the proposed 59-acre ponding area east of the Old Navajo County Fairgrounds may provide additional borrow fill. The existing levee fill was obtained from the 1945 borrow site and should be adequate as borrow for new construction".

Insert Plates 1 through 8, as follows:

APPENDIX

Geotechnical Engineering

Little Colorado River at Holbrock

Introduction

1. Purpose and Scope. The purpose of this report is to present preliminary geotechnical information for the design of the proposed structural improvements along the Little Colorado River. The geology and soils information presented in this appendix was assimilated to determine the extent, distribution and general physical properties of the rock and soils at and adjacent to the project site. The information was evaluated to determine the foundation and groundwater conditions and to provide a reasonable basis for the design of the proposed earth levees and the estimation of construction costs. No subsurface investigation or detailed laboratory soil testing have been conducted under this phase of the study.

2. Description of Project Features. The proposed project would provide flood protection by raising and lengthening the existing north bank levee from just east of Leroux Wash to a point approximately 6,800 feet east of the State Route 77 bridge. In addition, a levee will be constructed on the south bank from the Apache Railroad embankment, extending 3,400 feet eastward then hooking southward to higher ground. A small entrenched channel to provide for interior drainage behind the south levee would be constructed. A 59-acre ponding area east of the Old Navajo County Fairgrounds would be excavated 4 feet below existing grade to control drainage northeast of Holbrook. An existing low-flow channel excavated and maintained by the City of Holbrook would be reconstructed to a minimum depth of 4 feet. Based on preliminary hydraulic design considerations, levee slope protection consisting of 15 inches of riprap will be required. The slope facing will extend down to and incorporate the existing cutoff, or to a minimum depth of 10 feet elsewhere. Grouted stonework is to be provided over the area extending 200 feet upstream of the highway bridge to 200 feet downstream of the railroad bridge. See Plate 1 for general plan.

Regional Topography and Geology

3. The town of Holbrook is located primarily along the north bank of Little Colorado River approixmately 3 miles west of the confluence with the Rio Puerco. The river flows intermitteny after precipitation within its drainage basin and generally flows northwest. The river bed at Holbrook is generally wide and flat consisting mainly of fine alluvial sands and sporadic clayey silt lenses. The underlying bedrock in the area consists mainly of Permian and Triassic age sandstones. North of the town, a belt of Triassic conglomerate occurs. The terrain near Holbrook is comparatively flat,

although numerous, small, low-lying hills occur within the area. For many miles in extent, the region surrounding Holbrook is a part of the Mogollan Plateau, which is part of the Colorado Plateau province. The distinguishing features of this province are the nearly horizontal rock formations, the high altitude of the land surface and the development of numerous canyons despite the general aridity of the region.

Groundwater

4. Based on the well water depth recordings listed in Table I, for the wells located on Plate 1, it appears that groundwater will be encountered at shallow depths. Groundwater depths along the project reach will be evaluated, with greater certainty, during future design sudies and their related subsurface investigations.

Table I Observed Well Data

Well Date	Ground Elevation	Location	Depth to Water	Water Elevation	Thalweg Elevation
4/66-1	5165	3 1/2 miles SE of Holbrook	-54 ft	5111	5110
11/72-2	5080	3 miles W of Holbrook	-33 ft	5047	5048
3/68-3	5090	5 miles SW of Holbrook	-39 ft	5051	5055

Based on U.S.G.S. 15 min quad of Holbrook, Arizona.
See Plate 1 for well locations.

Seismicity

5. The project area is in Zone II on the Seismic Zone Map of the United States (Ref. ER 1110-2 30 Apr 1977) and is considered a moderate risk region. The largest known earthquake in the States's history was one of epicentral intensity VIII (modified Mercalli) recorded in 1910 approximately 75 miles northeast of Flagstaff. Structural features and locations of earthquake epicenters in Arizona are given on Plate 2. Pseudo-static analysis of the levee slopes during the design of the levee shomld be adequate to insure the stability of the structure.

Design Considerations

6. Foundation Conditions: The foundation conditions are adequate for the proposed improvements. The materials are primarily fine alluvial sands with intermittent clayey silt lenses. Bedrock, generally consisting of sandstone, should not be encountered during toe excavation or pilot channel construction. The groundwater table is relatively high and may present problems for heavy construction equipment during construction of the channel.

7. Levee Embankment: The levee embankment will require approximately 600,000 cubic yards of compacted fill. The embankment material will be compacted to at least 95 percent of maximum density (ASTM 698) at about optimum moisture content. Levee slopes will not be steeper than 1V on 2H.

8. Slope Protection: Based on preliminary hydraulic design studies, about 15 inches of riprap slope protection will be required. For the expected flow velocities of 8 fps, medium hard sandstone available in the area will provide adequate slope protection. The slope protection will extend below invert grade to provide scour protection. The toe excavation for the cutoff may require dewatering depending on the groundwater levels during construction. Excavated materials may be stockpiled and used for the toe backfill operations. Compaction may be accomplished by controlled wheel loadings.

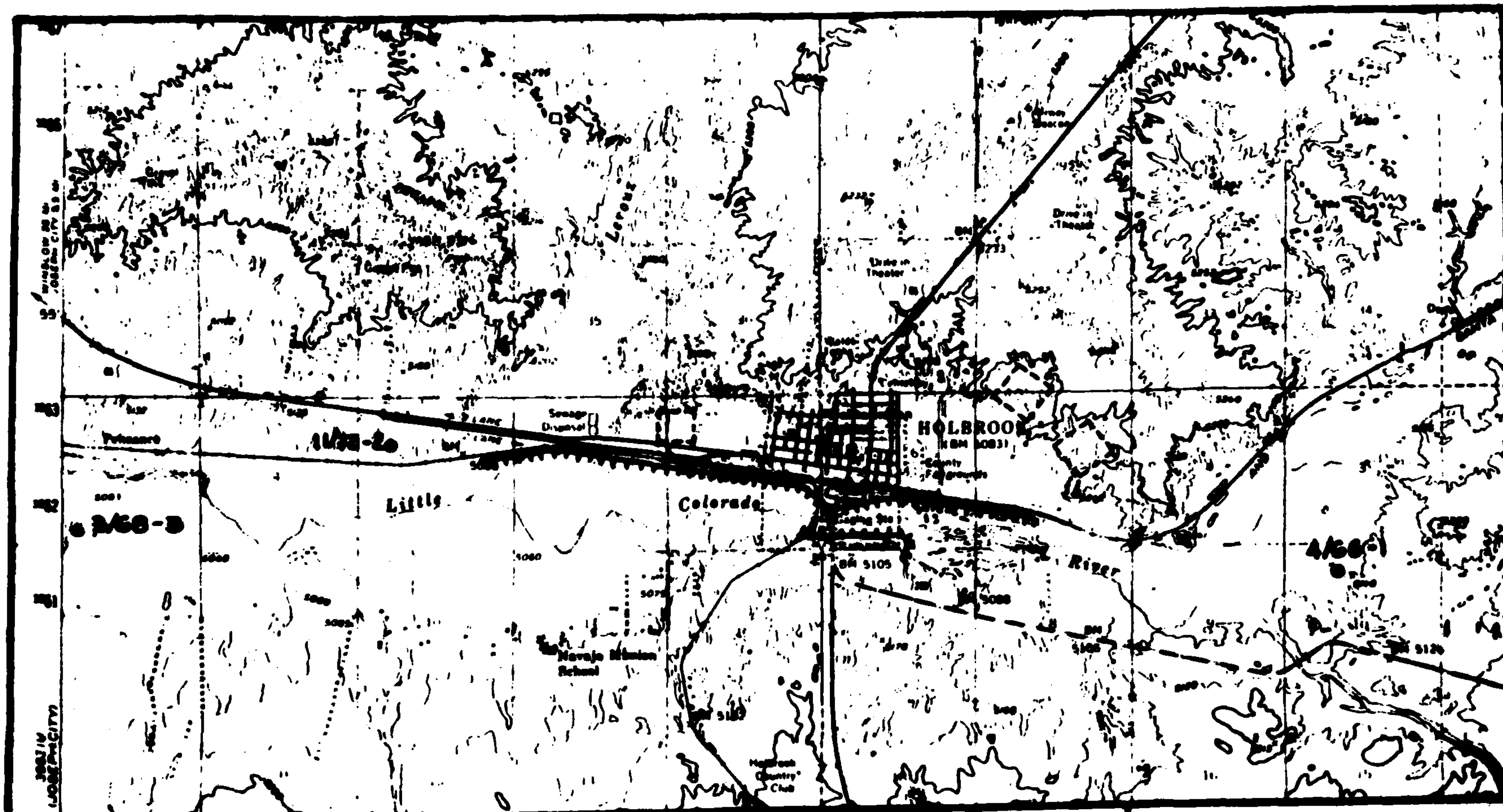
9. A graded gravel filter blanket will be required beneath the riprap. A filter blanket 6 inches thick should be adequate.

Construction Materials

10. Borrow Areas: Sufficient quantities of borrow materials may be obtained from designated borrow areas along the northern foothills bordering Holbrook, see Plate 1. Borrow site investigations, conducted in the project area, for the original Little Colorado River levee project by the Los Angeles District in 1945, indicate layers of clayey silt and silty sand, overlain by a layer of gravel along the northwest foothills. A similar soil profile is expected in the designated borrow areas. Native streambed materials consisting mainly of fine uncompacted alluvial sands are unsuitable for use in construction of the levee. Pending further site investigations, materials from the proposed 59-acre ponding area east of the Old Navajo County Fairgrounds may provide additional borrow fill.

11. Gravel Filter: Gravel of adequate gradation and quantity will be obtained from the designated borrow areas along the northern foothills bordering Holbrook.

12. Quarry Stone: Stone for the slope protection can be obtained from the quarry at Penzance siding located approximately 5 miles west of Holbrook. Based on testing done by the Los Angeles District in December of 1976, the quarry rock was found to be a medium hard sandstone.



KEY

● 3/60-3 WELL LOCATION

PROPOSED BORROW AREA

PROPOSED LEVEES

LITTLE COLORADO RIVER
AT HOLBROOK ARIZONA

PROJECT AREA
MAP

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

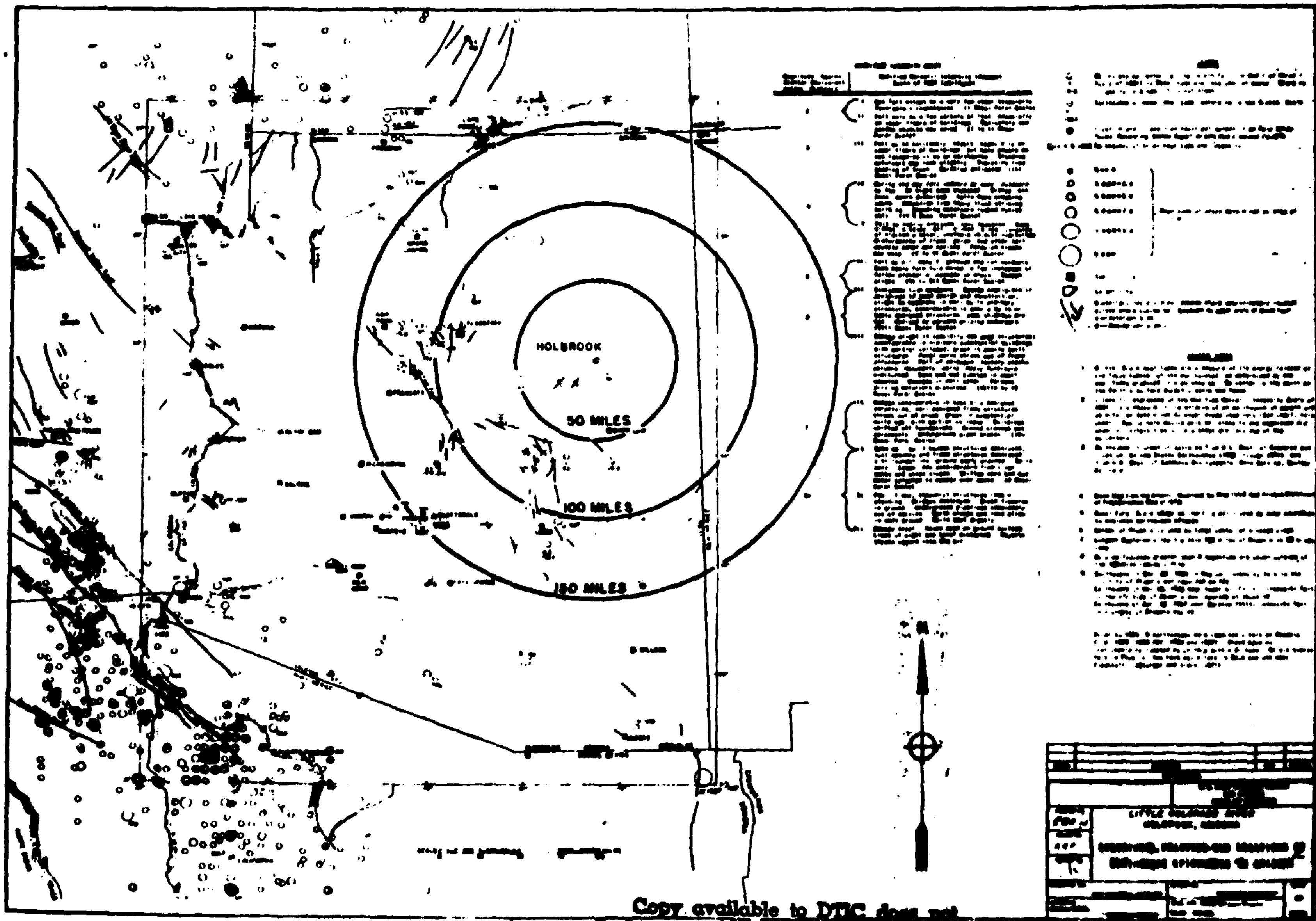


PLATE 2

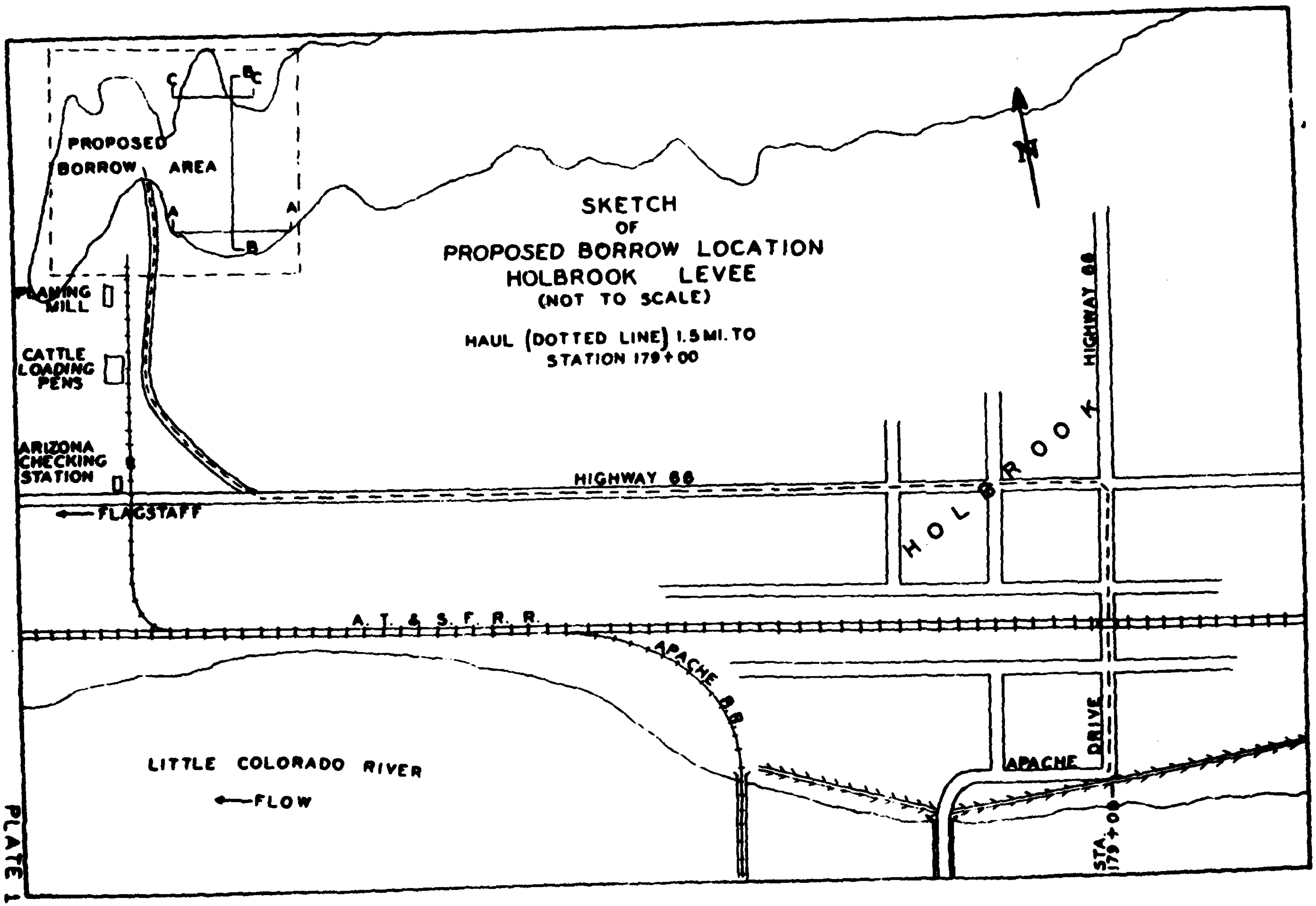
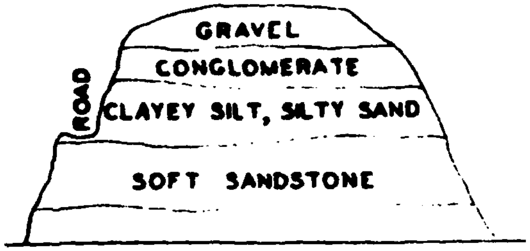
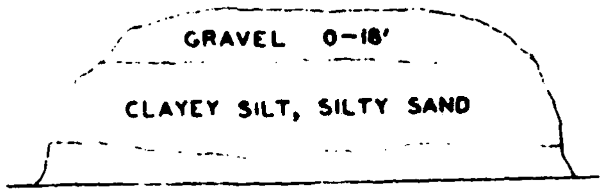


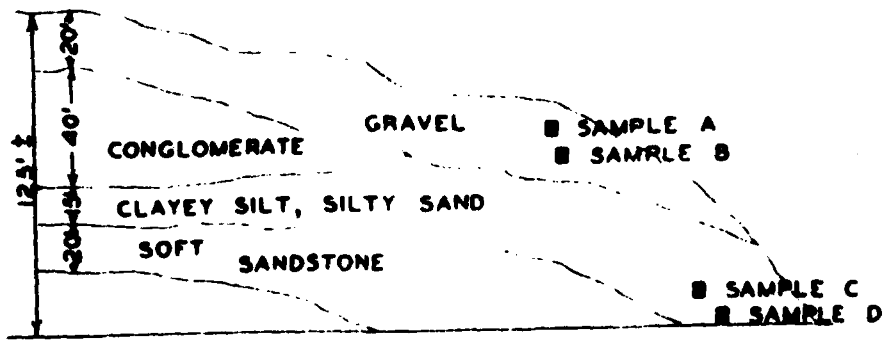
PLATE 1
AMENDMENT #1



SEC. A-A



SEC. C-C

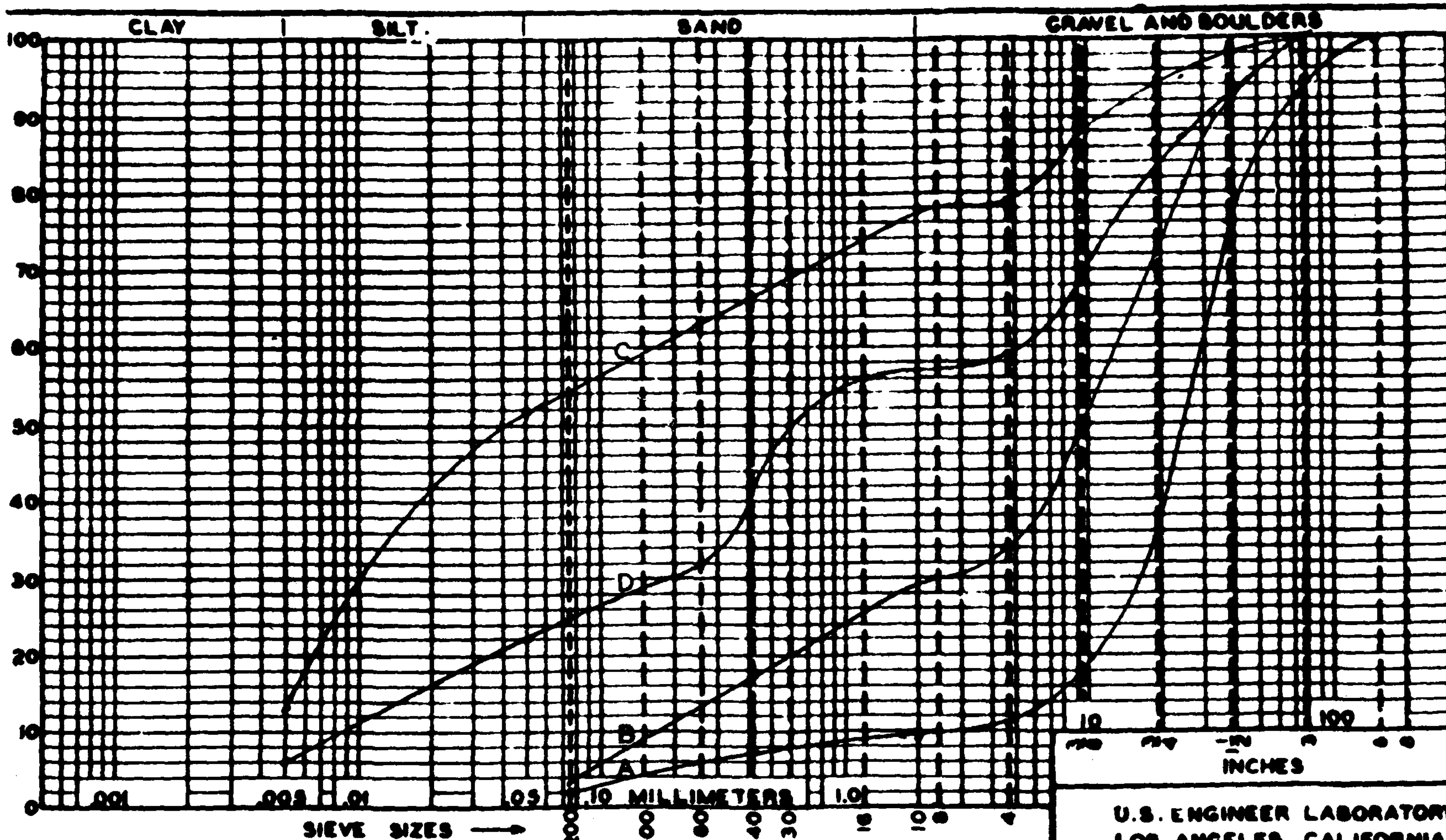


SEC. B-B

NOTE: STRATA APPROXIMATED FROM VISUAL INSPECTION.

SECTIONS
THROUGH
PROPOSED BORROW AREA
HOLBROOK LEVEE

PLATE 2
AMENDMENT #1



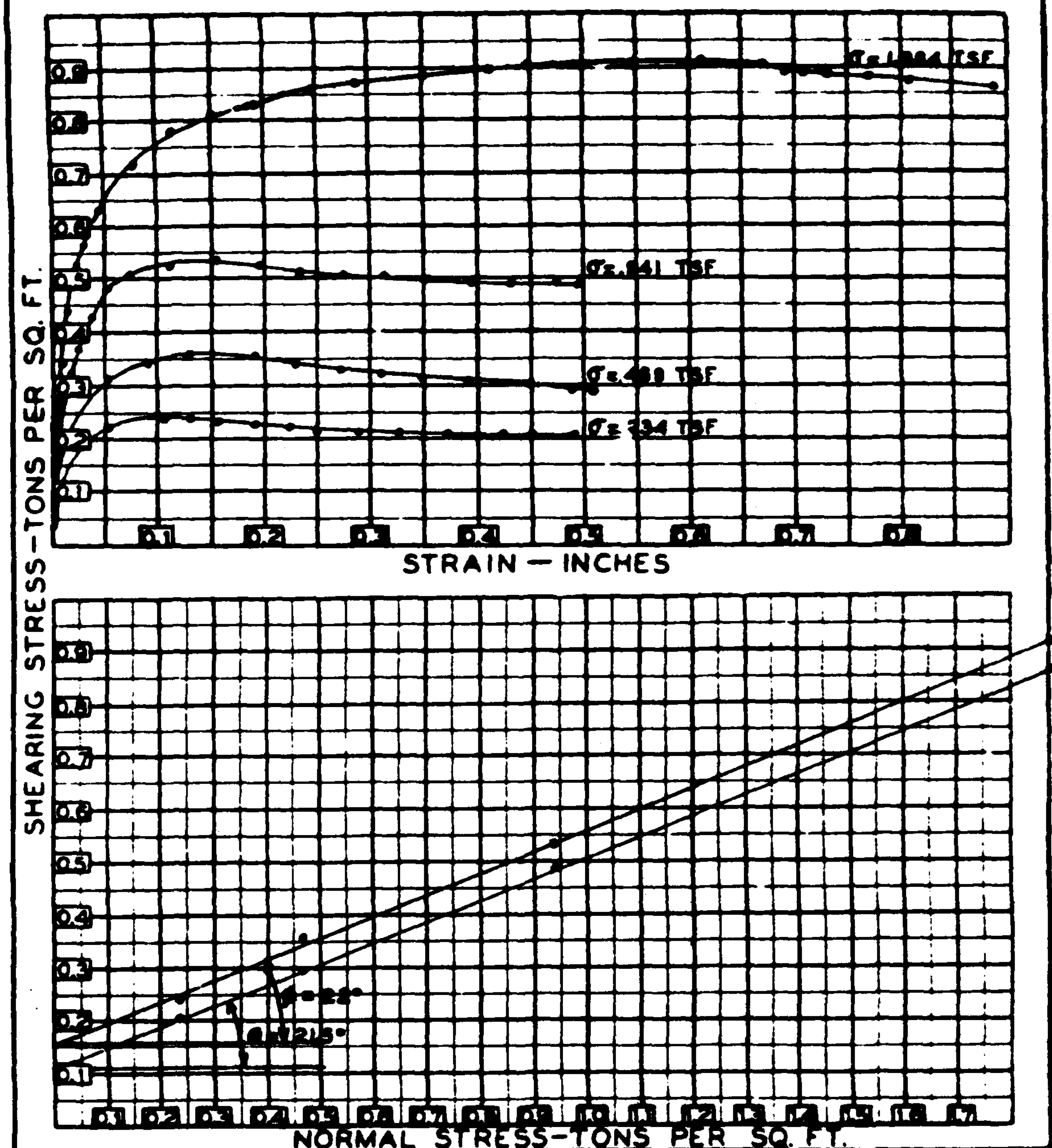
SAMPLE		DEPTH	PROPOSED USE TYPE OF MATERIAL
A			GRAVEL BLANKET, CLEAN GRAVEL
B			" " , CLEAN SANDY GRAVEL
C			EMBANKMENT, GRAVELLY CLAYEY SILT
D			" , GRAVELLY SILTY SAND

U.S. ENGINEER LABORATORY
LOS ANGELES, CALIFORNIA
LITTLE COLORADO RIVER
HOLBROOK, ARIZONA
PROPOSED BORROW MATERIAL
MECHANICAL COMPOSITION

DRAWN BY	CHECK BY	
E.W	D.D.F	

AMENDMENT #1 PLATE 3

WAR DEPARTMENT CORPS OF ENGINEERS, U. S. ARMY



	MAXIMUM	ULTIMATE
φ	22°	21.5°
TAN φ	.403	.396
COHESION, TSF	.156	.110

L.L.=23: P.L.=9

REMOLDED AT: 117 PCF, 12.5 % W.C.

MATERIAL PASSING NO. 10 SIEVE

U. S. ENGINEER OFFICE
LOS ANGELES, CALIF.

DIRECT SHEAR

LITTLE COLORADO RIVER
HOLBROOK, ARIZONA

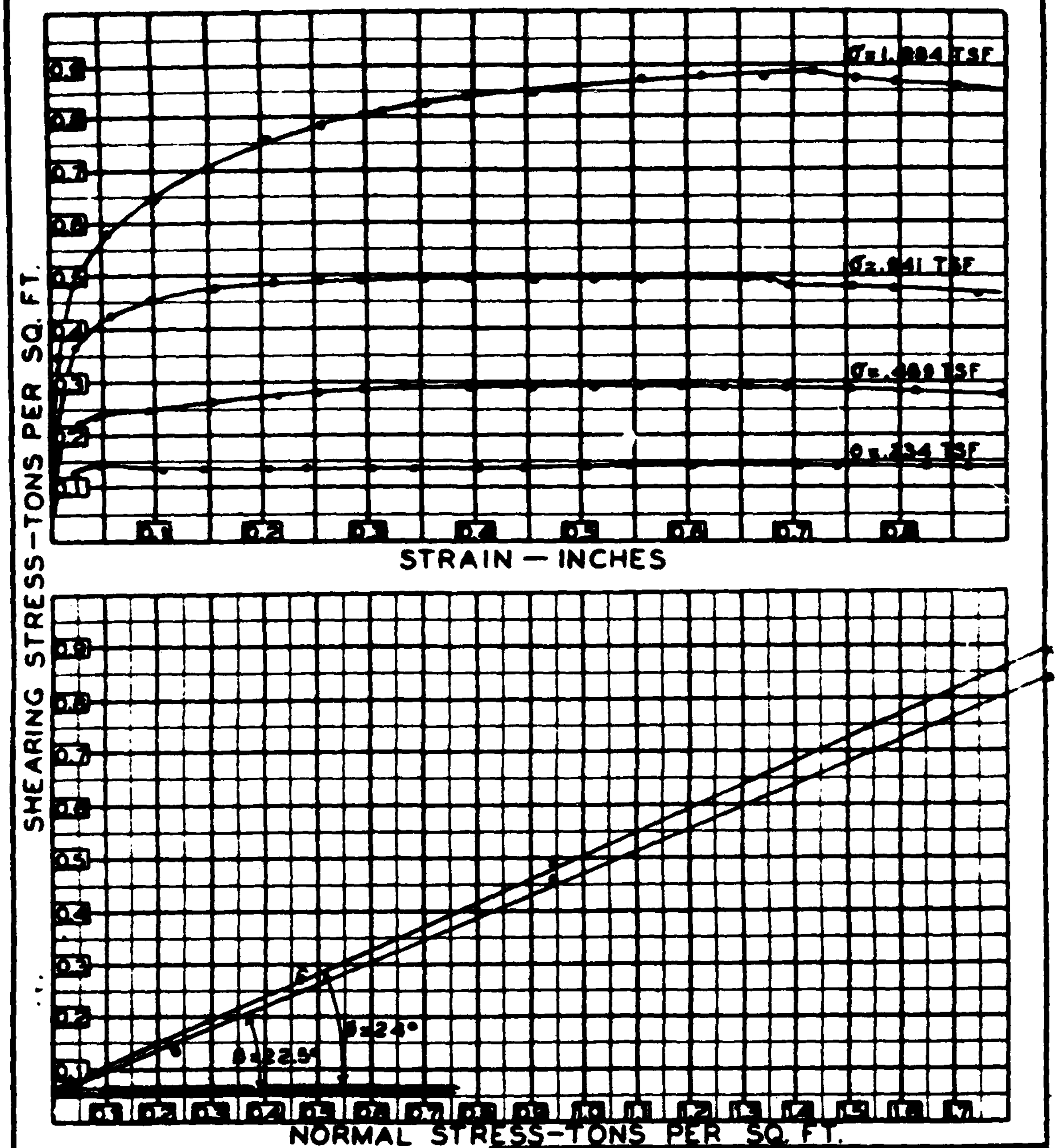
SAMPLE "D" SILTY SAND BORROW

TESTED	COMPUTED	CHECKED	DRAWN	
I. S.	I. S.	M.F.T.	I. S.	

PLATE 4

AMENDMENT #1

WAR DEPARTMENT — CORPS OF ENGINEERS, U. S. ARMY



	MAXIMUM	ULTIMATE
ø	24°	22.5°
TAN ø	.445	.414
COHESION, TSF	.065	.058

L.L.=26 P.I.=10

REMOLDED AT: 113 PCF, 12.5% W.C.

(MATERIAL PASSING NO. 10 SIEVE.)

U. S. ENGINEER OFFICE
LOS ANGELES, CALIF.

DIRECT SHEAR

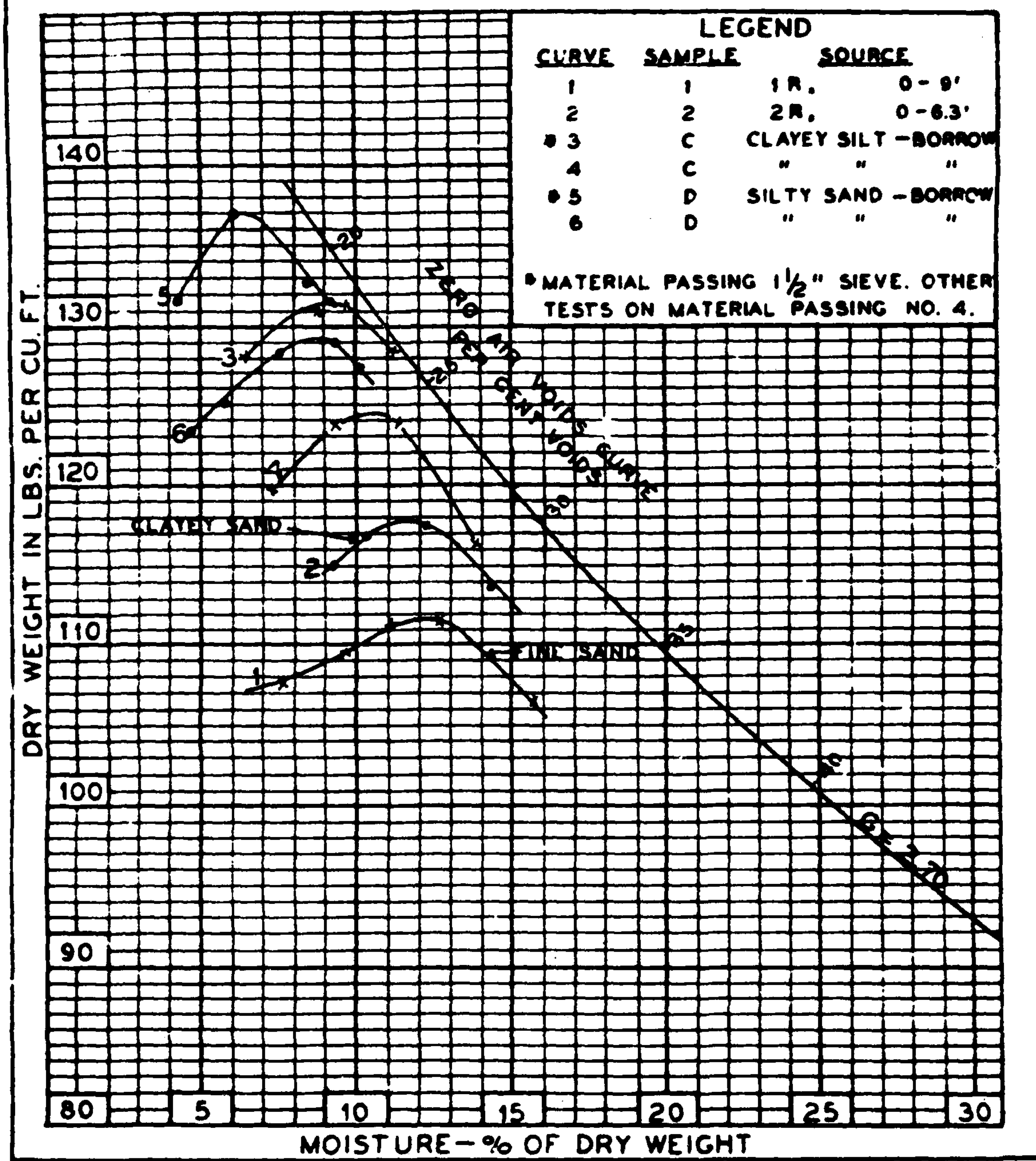
LITTLE COLORADO RIVER
HOLBROOK, ARIZONA

SAMPLE "C". CLAYEY SILT BORROW

TESTED	COMPUTED	CHECKED	DRAWN	
I. S.	I. S.	M.F.T.	I. S.	

PLATE 5

AMENDMENT #1



U. S. ENGINEER OFFICE
LOS ANGELES, CALIF.

COMPACTION

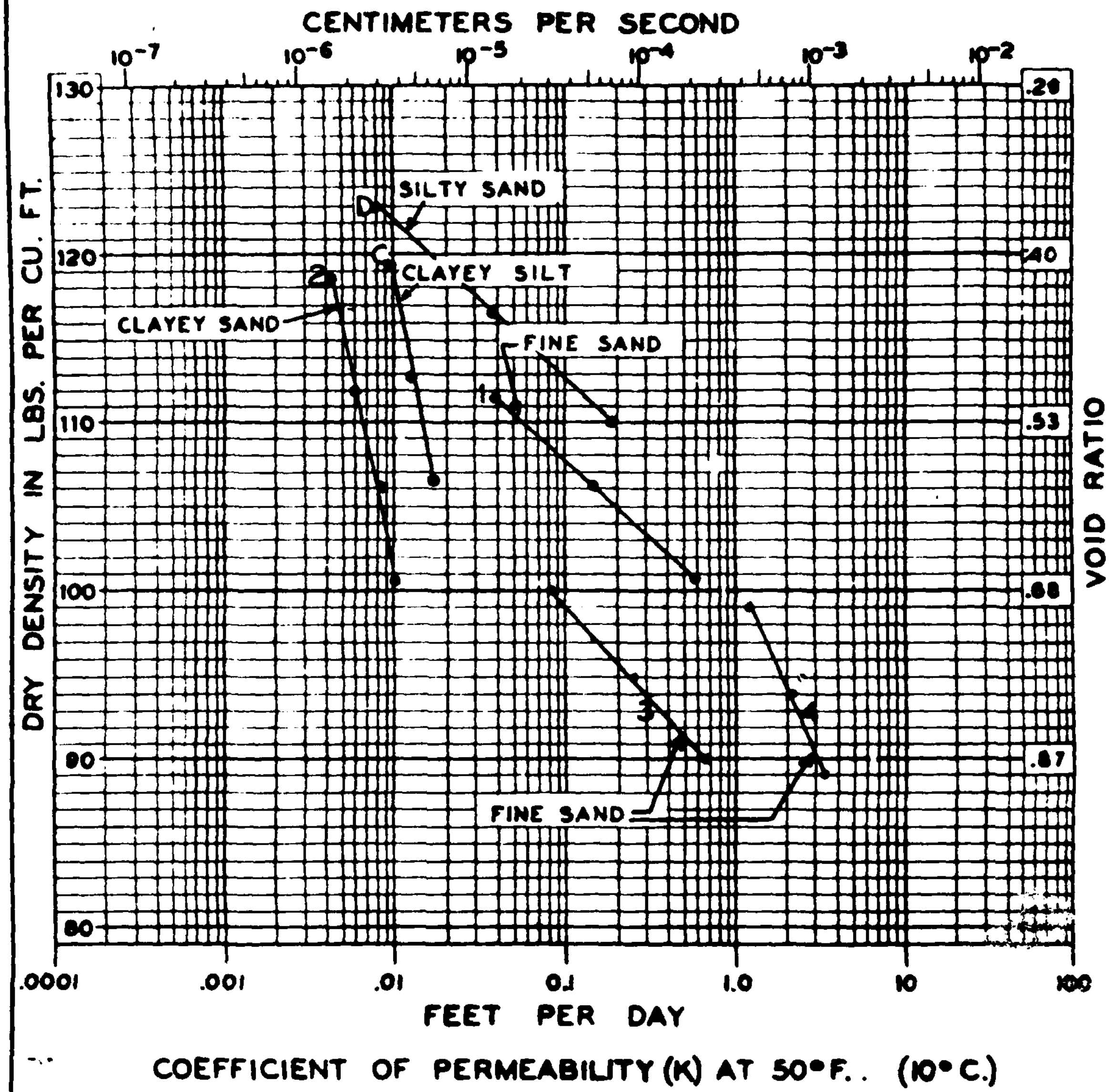
LITTLE COLORADO RIVER

HOLBROOK, ARIZONA

TESTED	COMPUTED	CHECKED	DRAWN
F. H.	F. H.	D. G. R.	G. F. C.

PLATE 6

WAR DEPARTMENT CORPS OF ENGINEERS, U. S. ARMY



AREA OF SAMPLE [illegible] SQ. INCHES
THICKNESS OF SAMPLE 1 & 2 INCHES

SAMPLE NO.	HOLE NO.	DEPTH, FT.
1	1 R	0 - 9
2	2 R	0 - 6.3
C	BORROW	
D	MATERIAL	
3	9 R	8 - 12
4	20 R	12 - 16

G = 2.70

U. S. ENGINEER LABORATORY
LOS ANGELES, CALIF

PERMEABILITY DATA

LITTLE COLORADO RIVER

HOLBROOK, ARIZONA

COMPILED BY	TESTED	COMPUTED	DRAWN	CHECKED
D. D. F.	F. M. M.	F. M. M.	C. F. C.	C. B. D.

PLATE 7

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